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GEOLOGY AND MINERAL DEPOSITS OF THE NORTHERN KECHIKA TROUGH BETWEEN GATAGA RIVER AND THE 60th PARALLEL

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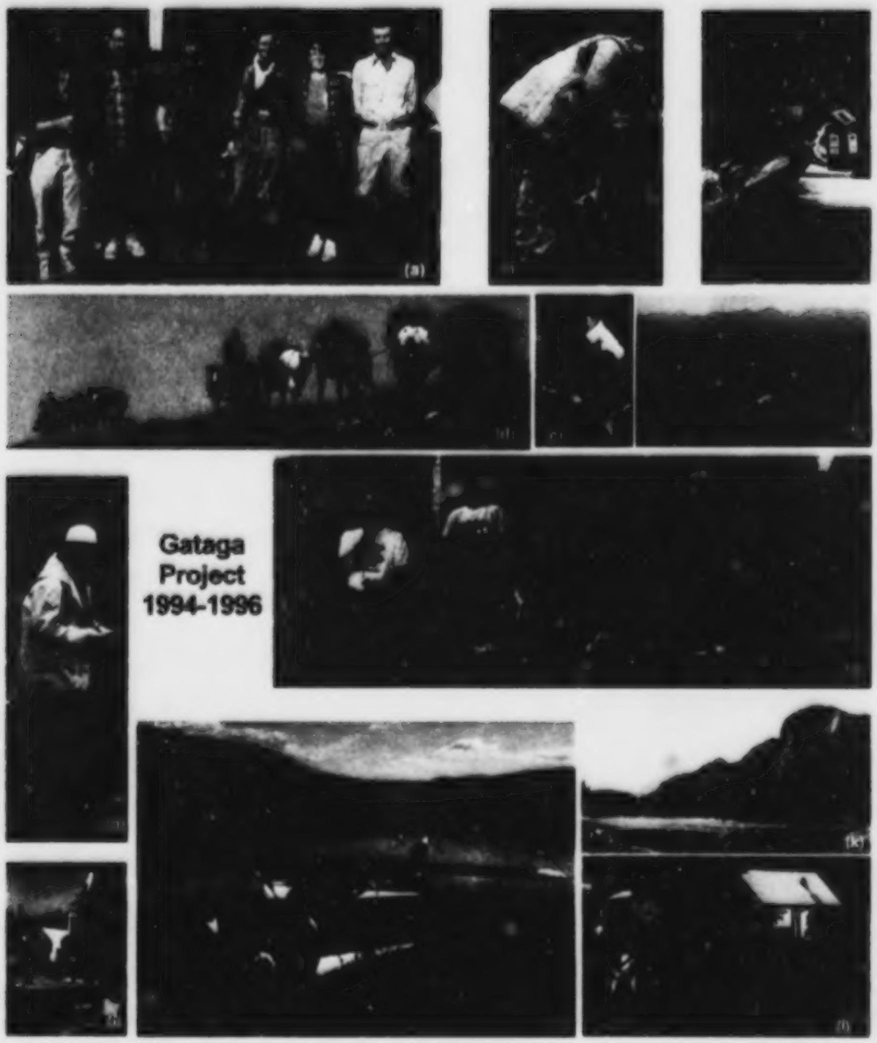

Frontispiece

(a) The 1995 field crew: (left to right) JoAnne Nelson, Andrew Legun, Eric Hou, Carole Augereau, Suzanne Paradis (Geological Survey of Canada) and Chris Rees. (b) Chris Rogers on a rainy day along the Red River canyon, July 1996. (c) The senior author contemplates setting up flycamp, August, 1995. (d) Andrew and JoAnn Knox move camp, east of Gataga Mountain, July, 1995. (e) Eric Hou cooks supper east of Gataga Mountain, July, 1995. (f) Andrew Knox and Andrew Legun admire the Northern Rocky Mountain Trench and the distant Cassiar Mountains from the western slopes of Gataga Mountain, June, 1995. (g) Chris Rees examines Cambrian siliciclastics on a rainy day, August, 1994. (h) The 1996 field crew: (left to right) Chris Rees, Chris Rogers, Hilda Reimer, Andrea Mills, Andrew Legun, JoAnne Nelson, Amy Thibeault (seated), Frontier Helicopter pilot, Jeremy Valeriote, Dorthe Jakobsen. (i) Dorthe Jakobsen, Hilda Reimer and Chris Rogers prepare for an assault on Tatisno Mountain, July, 1996. (j) A Beaver brings in supplies to the Graveyard Lake camp, July, 1996. (k) Looking north along the Gataga River valley, 10 kilometres upstream from its confluence with the Kechika River, August, 1994. (l) Andrew Knox rounds up some horses in preparation for moving camp from Terminus Mountain to the west side of Gataga Mountain, June, 1995.

ABSTRACT

The Kechika Trough represents a Lower Paleozoic basin developed between the MacDonald Platform to the east and the Cassiar Platform to the west. This basin was well established by Late Cambrian time and ceased to be a depositional entity at the beginning of the Late Devonian. Mapping along the western part of the trough, between the Gataga River and the 60th parallel, encountered layered rocks of Proterozoic to Cenozoic age. These include: Late Proterozoic siliciclastics, carbonates and volcanics; siliciclastics and carbonates of Cambrian age; Late Cambrian to Early Ordovician calcareous argillites and argillites of the Kechika Group; slate, siltstone and minor limestone of the Middle Ordovician to Middle Devonian Road River Group; Late Devonian to Early Mississippian argillite, chert and minor limestone of the Earn Group; chert, tentatively assigned to the Mississippian to Permian Mount Christie Formation; conglomerate and sandstone of possible Tertiary age; and Tertiary to Quaternary mafic volcanics assigned to the Tuya Formation. Intrusive rocks represent a very minor component of the map area and consist of Early Paleozoic sills and dikes of gabbroic composition, feldspar porphyry dikes of Cretaceous or Tertiary age and small Early Cretaceous stocks, dikes and sills of broadly granitic composition.

Periodic extensional tectonism during the Paleozoic, which led to the formation and subsequent modification of the Kechika Trough, was followed by intense, easterly directed, compressional tectonics and associated metamorphism of Mesozoic age, resulting in the present structural configuration. Rocks of the trough belong to the Rocky Mountain structural province and structures are dominated by easterly verging folds and thrusts. Thrust faulting predominates in the southern part of the map area where lithologies are dominated by thick, competent Cambrian carbonate and quartzite units. Their disappearance to the north results in a structural style dominated by folding and penetrative cleavage.

Sedimentary exhalative mineralization (sedex) represents the most important mineral deposit type found within the Kechika Trough, ranking it, and the more northerly Selwyn Basin, as one of the most important metallotects of the Canadian Cordillera. These stratiform Zn-Pb-Ag-Ba deposits are found at several stratigraphic levels: Cambrian, Middle Ordovician, Lower Silurian and Upper Devonian. Upper Devonian deposits are by far the most numerous and economically important within the map area, and throughout the Kechika and Selwyn basins. The large Cambrian and Early Silurian deposits found in the Anvil and Howards Pass districts, respectively, highlight the potential that all these horizons have for hosting economically significant sedex deposits. Tungsten - molybdenum porphyry/skarn mineralization related to Early Cretaceous intrusions is the next most important mineral deposit type. Minor lead, zinc and copper-bearing veins are scattered throughout the map area.

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CHAPTER 1 INTRODUCTION

Cambrian to Mississippian rocks, deposited in the northwest trending Kechika Trough, are exposed along the western margin of the northern Rocky Mountains. The basin is host to numerous sedimentary exhalative barite-lead-zinc deposits, collectively known as the Gataga mineral district. Deposits occur at various stratigraphic levels, although the most numerous and economically important are Upper Devonian, such as the Cirque (Stronsay) and Driftpile deposits (Figure 1).

The British Columbia Ministry of Energy and Mines Petroleum Resources began a multi-disciplinary study of the northern part of this basin during the summer of 1994. This was a cooperative project with the Geological Survey of Canada and was funded, in part, by the second Mineral Development Agreement between the governments of British Columbia and Canada. This report summarizes the bedrock mapping component of this multi-disciplinary effort, which included a detailed study of the Driftpile deposits (Nelson *et al.*, 1995; Paradis *et al.*, 1995, 1996; Paradis *et al.*, 1998), a regional stream-sediment and water survey covering the southern third of the bedrock map area (Jackaman *et al.*, 1996), a regional lake-sediment and water survey over the northern two thirds of the bedrock map area (Cook *et al.*, 1997, 1999) and a characterization of the geochemical signature of the Driftpile occurrences (Lett and Jackaman, 1995). Field data for the bedrock mapping component of this program was collected during the summers of 1994, 1995 and 1996.

The Gataga mapping project straddled the eastern side of the Northern Rocky Mountain Trench and extended northwestwards from the confluence of the Gataga and Kechika rivers to the British Columbia-Yukon border (Figures 2, 3, 4, 5). This area covers the western Muskwa Ranges of the northern Rocky Mountains which drop off into the Liard Lowlands (Figure 6). The varied topography of this region reflects the northward termination of the Rocky Mountains. Terminus Mountain is the last 'Rocky' Mountain along the northern trace of this extensive mountain belt. The rugged terrain south of Terminus Mountain results from the presence of thick sections of resistant Cambrian carbonates and quartzites which have been further thickened into folded thrust stacks typical of the Rocky Mountains (Photo 1). These lithologies 'shale out' north of Terminus Mountain and the resulting, relatively incompetent lithologies, form the subdued topography of the Rabbit Plateau and Liard Lowlands (Photo 2).

The bulk of the area is remote and primary access is by air. There is no vehicle access to the map area, except through the northernmost part which is traversed by the Alaska Highway. The small village of Lower Post, on the Alaska Highway, is the only community within the map area. The centre of the map area is approximately 175 kilometres northeast Dease Lake and 125 kilometres south southeast of Watson Lake. The larger community of Fort Nelson is some 260 kilometres distant, and Fort St. John and Mackenzie are 500 kilometres to the southeast. The best access to the region is through Watson Lake, the only viable source of supplies. It offers the added benefit of a relatively safe bad-weather access route along the Northern Rocky Mountain Trench.

The southern end of the map area adjoins mapping by McClay *et al.* (1988) along the north end of Forsberg Ridge (Figure 7). The eastern boundary approximately corresponds to the eastern limit of preserved Earn Group rocks in this part of the Foreland Belt. This roughly follows the Netson Creek and the Rabbit River valleys, extends north to Tatisno Mountain, and then northwestward to the British Columbia-Yukon border. The western part of the map area is bounded by the Northern Rocky Mountain Trench.

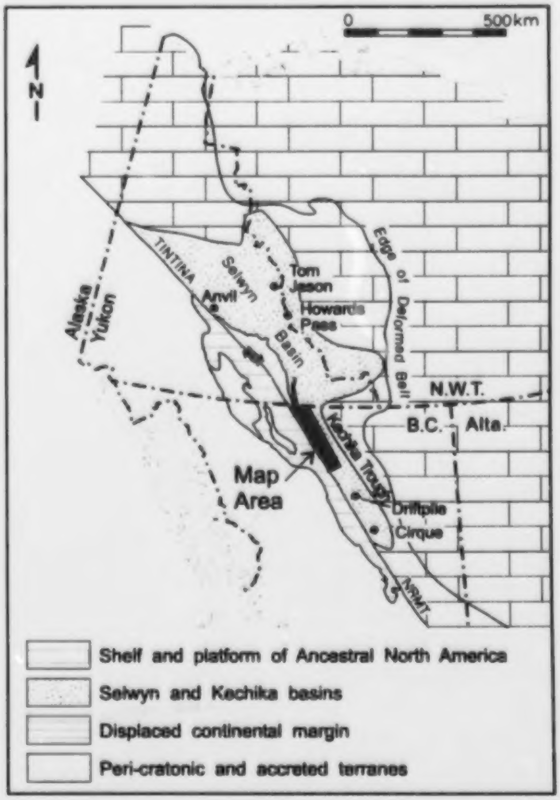

Figure 1. Simplified map of the northern part of the Canadian Cordillera showing location of the project area with respect to the shelf-off-shelf boundary during Ordovician to Silurian time. Also shown are the major sedex mineral deposits within the Selwyn and Kechika basins (modified from Cecile and Norford, 1991). NRMT-Northern Rocky Mountain Trench.

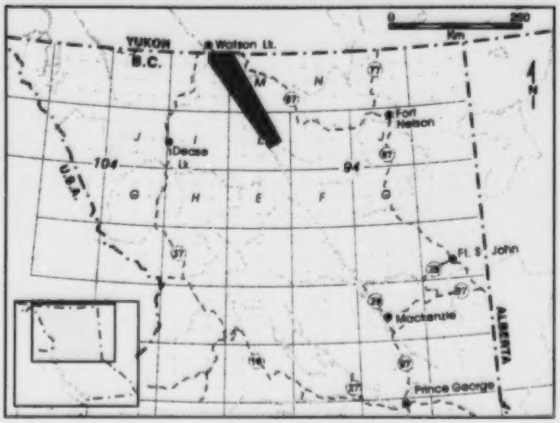
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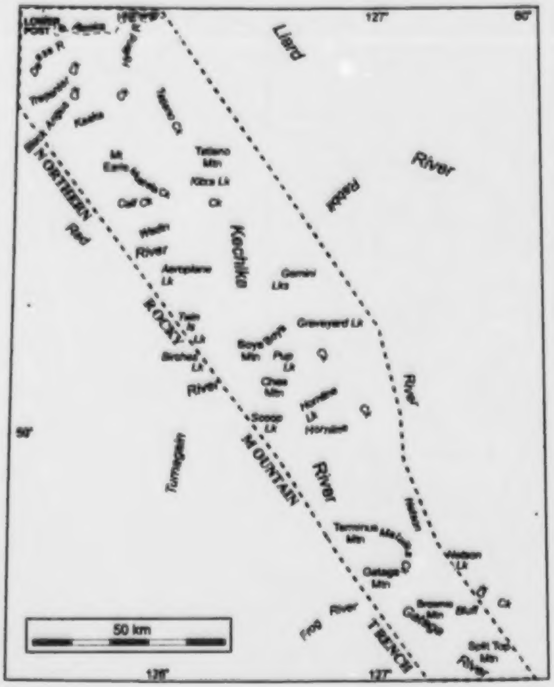
Figure 4.Northeastern British Columbia showing the location of the project area together and major highways, waterways and the National topographic grid system.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River
Turnagain
Frog
River
Gataga
Terminus Mtn
Graveyard Lk
Gemini Lks
Aeroplane Lk
Mt Ealue
Tetano Mtn
Kitza Lk
Gataga Mtn
Horneline
50°
50 km
126°
127°

Figure 5. Main geographic elements mentioned in the text. Map area shown by dotted lines.

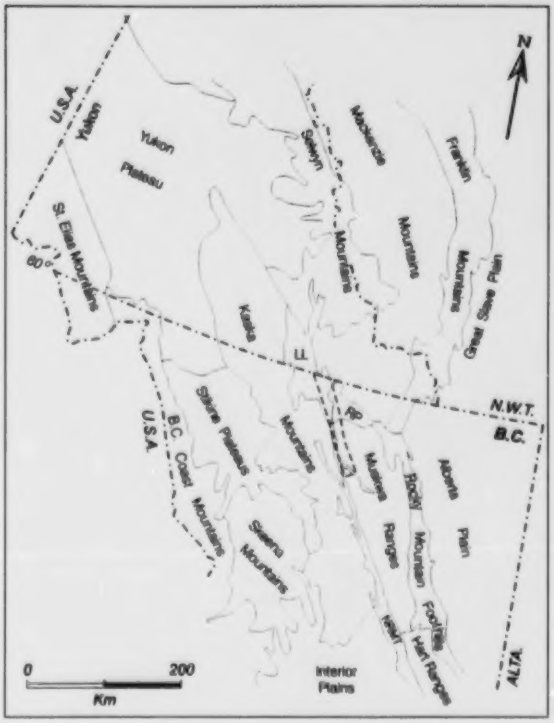
N
U.S.A.
Yukon
Yukon Plateau
St. Elias Mountains
60°
Selwyn Mountains
Mackenzie Mountains
Franklin Mountains
Great Slave Plain
Kaska
LL
RP
N.W.T.
B.C.
U.S.A.
B.C.
Coast Mountains
Stikine Plateau
Cassiar Mountains
Skeena Mountains
Muskwa Ranges
Rocky Mountain Foothills
Alberta Plain
Hart Ranges
Interior Plains
ALTA.
0
200
Km

Figure 6. Location of the map area with respect to main physiographic elements of the northern Canadian Cordillera. Modified from Mathews (1986). RP: Rabbit Plateau; LL: Liard Lowlands; NRMT: Northern Rocky Mountain Trench.

The southern tip of the map area, between Gataga River and Forsberg Ridge, is characterized by subdued, glaciated terrain and the amount of exposure is less than 5 per cent. Exposure increases dramatically northwest of the Gataga River with nearly 100 per cent outcrop along ridges underlain by Cambrian carbonate rocks between there and Terminus Mountain (Photo 3). The area within the Rabbit Plateau (between Terminus Mountain and Graveyard Lake) is more subdued; only the tops of hills reach timberline and outcrop density is approximately 5 per cent. The Liard Lowland extends into the area north of Graveyard Lake and outcrop density is considerably less than 1 per cent.

PREVIOUS WORK

Reconnaissance-scale mapping along the northern part of Kechika Trough was first carried out by Gabrielse (1962a, b, 1963 and 1981), Gabrielse *et al.*, (1977) and Taylor (1979; Figure 7). Gabrielse mapped the Kechika (94L), Rabbit River (94M), Ware (94F, west half) and McDame areas at a 4-mile scale, while Taylor worked in the Ware (94F, east half) and the Trutch (94G) map areas. The southern parts of the trough have been mapped by Gabrielse (1975) in the Mesilinka River area (west half) and by Thompson (1989) in the Halfway River (94B) area. West of the Kechika sheet, the Cry Lake (104I) map area has recently been released at 1:100 000 and 1: 250 000 scales (Gabrielse, 1998). Taylor and Stott (1973) describe the miogeoclinal shelf sequence immediately east of the study area. Rocks of the adjoining Selwyn Basin to the north have been mapped by Gabrielse (1967) in the Watson Lake area (105A) and Gabrielse and Blusson (1969) in the Coal River area (95D).

Photo 1. Looking south at Gataga Mountain. This picture shows the typical ruggedness of the alpine areas within the map area.

Photo 2. Looking north towards Graveyard Lake from the northern slopes of Chee Mountain. This view of the Rabbit Plateau illustrates the subdued terrain found throughout the northern part of the map area.

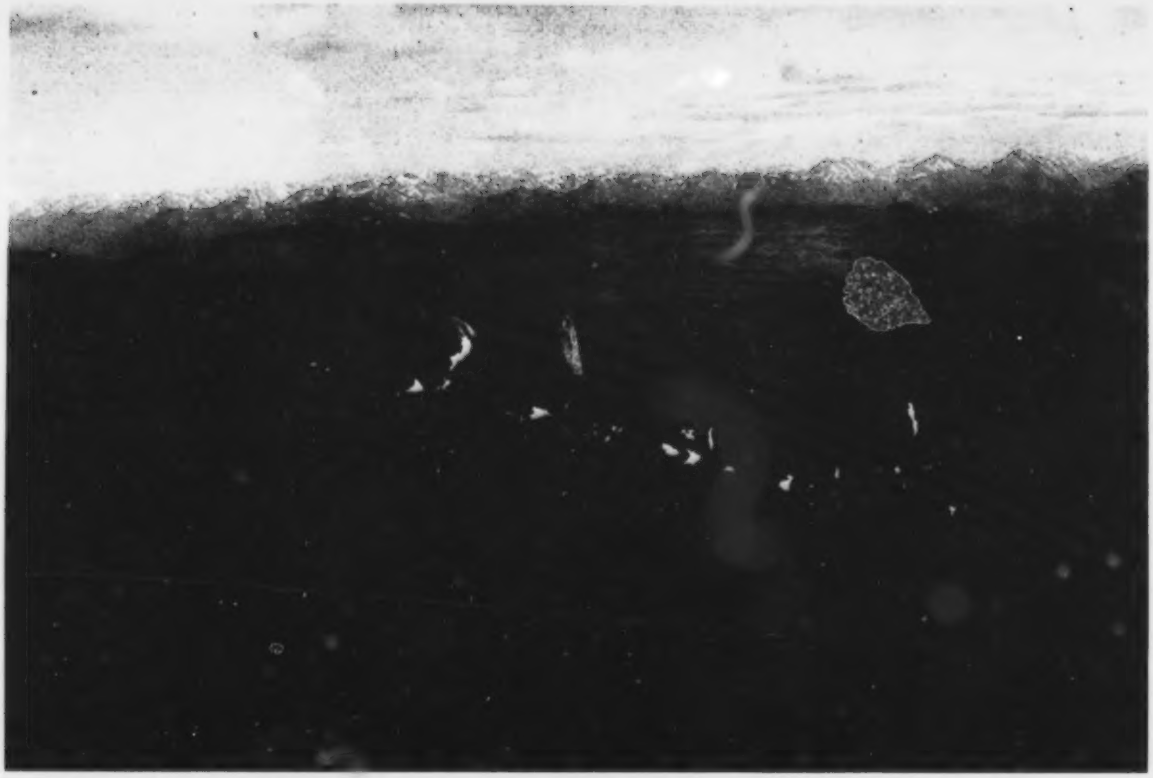

Photo 3. View to the south with Split Top Mountain in the foreground, Forseberg Ridge in the middle ground and the Cassiar Mountains in the distance, across the Northern Rocky Mountain Trench. This picture illustrates the contrasting terrains found in the southern part of the map area. The ruggedness of Split Top Mountain reflects the underlying Cambrian carbonate rocks. The more subdued terrain to the east, and along Forseberg Ridge is underlain by the more incompetent Lower Paleozoic rocks which are dominated by shaly lithologies. These latter rocks predominate in the northern part of the map area, and together with glacio-fluvial activity, resulted in the rolling hills and plains of the Rabbit Plateau and Liard Lowlands.

More detailed mapping was conducted by MacIntyre (1998, 1980a, b, c; 1981a, b, 1982a) in the Akie River area and by McClay and Insley (1986) and McClay *et al.* (1987, 1988) between Driftpile Creek and Gataga River.

Early studies describing Ordovician and Silurian stratigraphy along the western part of the Kechika Basin include Jackson *et al.* (1965) and Norford *et al.* (1966). Taylor *et al.* (1979) elucidated the stratigraphy in the Ware (east half) map area. Fritz (1979, 1980a, 1991) detailed stratigraphic sections and relationships within Cambrian rocks of the Kechika Basin and the adjacent shelf sequence. Cecile and Norford (1979) described the stratigraphic relationships along the transition between shelf and off-shelf facies in Ordovician and Silurian strata. Norford (1979) discussed Early Devonian graptolites within uppermost Road River strata between the Kwadacha and Akie rivers. A balanced structural cross-section extending from south of Fort Nelson, across the centre of the Kechika Trough and to Gravina Island in southeastern Alaska was produced by Gabrielse and Taylor (1982).

Published accounts of the economic potential of this area date to the early 1980s, after nearly a decade of exploration within the Selwyn and Kechika basins. Early descriptions of the resource potential and exploration models for the Kechika Basin are provided by Carne and Cathro (1982) and MacIntyre (1982b, 1983). MacIntyre (1980b), Jefferson *et al.* (1983) and Pigage (1986) described the geologic setting of the Cirque deposit. MacIntyre and Diakow (1982) gave a brief account of the Kwadacha mineral occurrence and Irwin and Orchard (1989) refined the timing of mineralization in the Kechika and Selwyn basins. MacIntyre (1991, 1992) provided an overview of sedex mineralization within the southern Kechika Trough. Preliminary work by Nelson *et al.* (1995) and Paradis *et al.* (1995, 1996) has been synthesized into a detailed account of the timing and nature of Late Devonian sedimentary exhalative mineralization in the southern Kechika Trough (Paradis *et al.*, 1998).

The present report not only draws from these reports and maps but builds on preliminary work by these authors within the Kechika Trough, and by Ferri *et al.* (1995a, b; 1996a, b and 1997a, b).

ACKNOWLEDGMENTS

The authors would like to thank the following field assistants (*see* Frontispiece): Carole Augereau (1994, 1995),

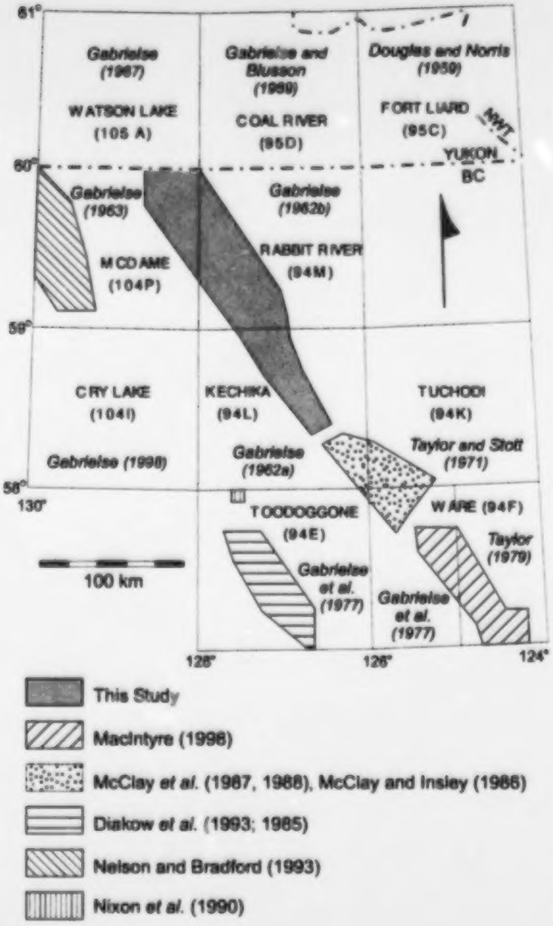
61°
Gabrielse (1967)
WATSON LAKE (105 A)
Gabrielse and Blusson (1969)
COAL RIVER (95D)
Douglas and Norris (1959)
FORT LIARD (95C)
NWT
YUKON
BC
60°
Gabrielse (1963)
MCDAME (104P)
Gabrielse (1962b)
RABBIT RIVER (94M)
59°
CRY LAKE (104I)
Gabrielse (1998)
KECHIKA (94L)
Gabrielse (1962a)
TUCHODI (94K)
Taylor and Stott (1971)
58°
130°
TOODOGGONE (94E)
WARE (94F)
Taylor (1979)
Gabrielse et al. (1977)
Gabrielse et al. (1977)
100 km
128°
126°
124°
This Study
MacIntyre (1998)
McClay et al. (1987, 1988), McClay and Insley (1986)
Diakow et al. (1993; 1985)
Nelson and Bradford (1993)
Nixon et al. (1990)

Figure 7. Bedrock mapping in and adjacent to the present project area.

Eric Hou (1995), Dorthe Jakobsen, Andrea Mills, Amy Thibeault, Chris Rogers and Jeremy Valeriote (1996). A special mention goes to Suzanne Paradis of the Geological Survey who assisted with several days of mapping at the end of the 1995 field season. A very special thanks goes to Hilda Reimer for the wonderful meals she produced during our stay at Graveyard Lake (1996).

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REGIONAL SETTING

Most of the map area lies along the western margin of the Rocky Mountain subprovince of the Canadian Cordilleran Foreland Belt (McMechan and Thompson, 1991; pages 635-642; Figure 8). The northwestern tip of the study area lies within the Selwyn Fold Belt and is part of the Omineca Belt (Gordey and Thompson, 1991; pages 625-630). Its western boundary follows the Northern Rocky Mountain Trench fault zone, a southern extension of the Tintina fault zone, both of which separate displaced continental rocks of the Omineca Belt from ancestral North American strata of the Rocky Mountains (Figure 1). The Omineca Belt, across the Northern Rocky Mountain Trench fault zone, is represented by rocks of the Cassiar Terrane which bear similarities to those of the Northern Rocky Mountains, although direct correlation is precluded by 450 to 750 kilometres of right-lateral displacement along the trench (Tempelman-Kluit, 1977; Gabrielse, 1985).

The Rocky Mountain subprovince is characterized by northeasterly folded and thrusted rocks of mainly Paleozoic and older strata (McMechan and Thompson, 1991). Almost all strata within the map area range in age from Late Proterozoic to early Mississippian and record several depositional settings along the ancestral North American margin. The main depositional element in the map area is the Paleozoic, northwest-trending Kechika Trough which connects to the northwest with the Selwyn Basin in Yukon Territory (Figure 1). The Selwyn and Kechika basins were filled with finer grained, deeper water equivalents of coeval shelf and platform strata to the east. The geometry of the Kechika Basin is interpreted as either a westward-deepening basin (H. Gabrielse, personal communication, 1994) or as a narrow trough or embayment surrounded on three sides by shallower water facies (MacIntyre, 1992, 1998, McClay *et al.*, 1988; this study). Rocks of the Kechika Trough were deposited on rift-related clastics of Late Proterozoic age which record the establishment of a passive continental margin by the end of the Precambrian. The basin was best developed during Ordovician to Devonian time, when thick, carbonate shelf sequences shaled out abruptly westward into off-shelf, fine-grained siliciclastic and carbonate rocks of the Road River Group (Cecile and Norford, 1979; Thompson, 1989; Figure 9). A much broader, westward carbonate-to-shale transition is also present in Cambro-Ordovician strata of the Kechika Group (Cecile and Norford, 1979). Middle to Upper Cambrian carbonates also shale-out to the west, although this transition is complicated by linear,

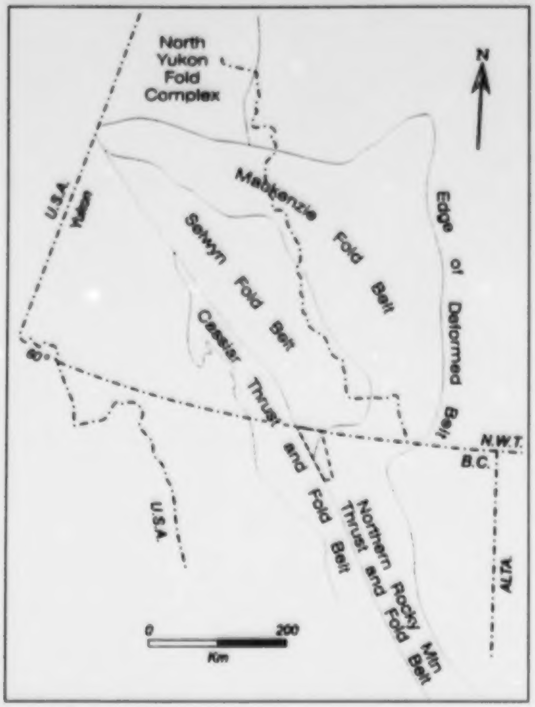

North Yukon Fold Complex
N
U.S.A.
Yukon
Mackenzie Fold Belt
Selwyn Fold Belt
Edge of Deformed Belt
Cassiar Thrust and Fold Belt
60°
N.W.T.
B.C.
U.S.A.
Northern Rocky Mtn Thrust and Fold Belt
ALTA.
0
200
Km

Figure 8. Location of the study area in relation to major structural subdivisions of the northeastern Canadian Cordillera. (modified from McMechan and Thompson, 1991; Gordey and Anderson, 1993).

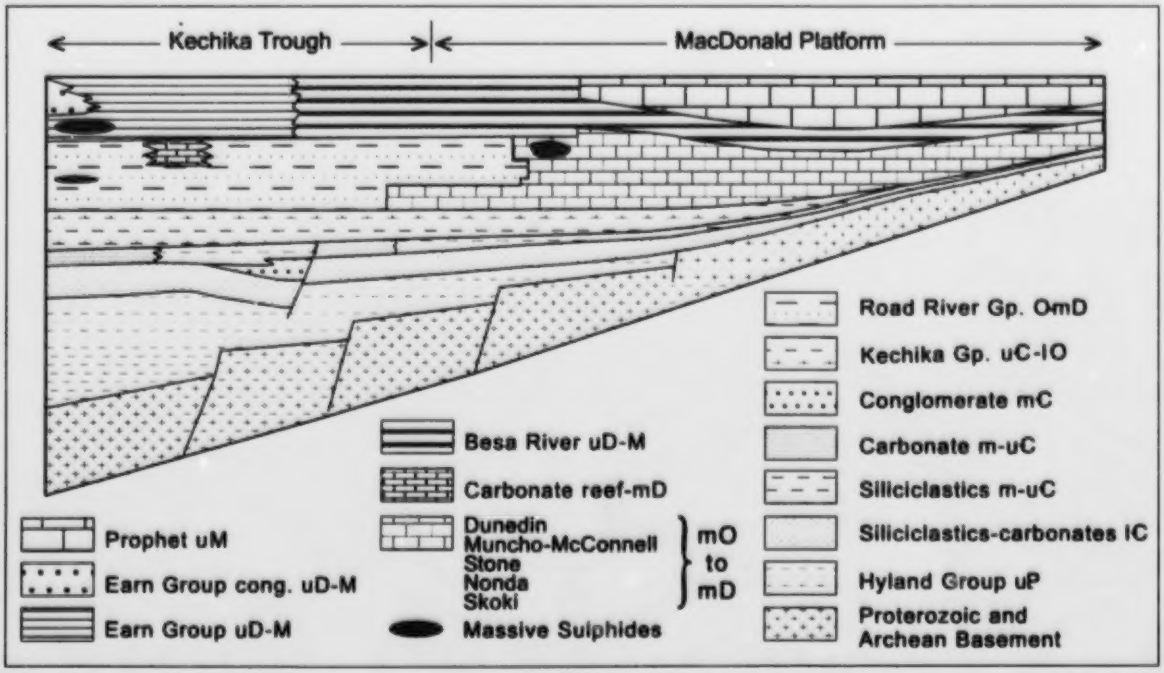

Kechika Trough
MacDonald Platform
Road River Gp. OmD
Kechika Gp. uC-lO
Conglomerate mC
Carbonate m-uC
Siliciclastics m-uC
Siliciclastics-carbonates lC
Hyland Group uP
Proterozoic and Archean Basement
Besa River uD-M
Carbonate reef-mD
Dunedin
Muncho-McConnell
Stone
Nonda
Skoki
mO to mD
Massive Sulphides
Prophet uM
Earn Group cong. uD-M
Earn Group uD-M

Figure 9. Simplified restored section of western ancestral miogeocline along the southern Kechika Trough. Datum is the top of the Earn Group, and Besa River and Prophet formations. Modified from Gabrielse and Yorath, 1991; Thompson 1989. P - Proterozoic; C - Cambrian; O - Ordovician;; D - Devonian; M - Mississippian; l - lower; m - middle; u - upper.

north-trending reefal build-ups in the western part of the basin (Fritz, 1979, 1980a, 1991; Gabrielse and Yorath, 1991). Similar carbonate build-ups are found at the Middle Devonian level in the centre of the basin (Akie reefs; MacIntyre, 1992).

Fine-grained siliciclastics and minor limestone of the Upper Devonian Earn Group, and its eastern equivalent the Besa River Formation, reflect a fundamental change in deposition across the western miogeocline. These rocks record the abrupt end of shallow-water carbonate deposition within the eastern miogeocline and the subsequent laying down of deeper water, fine-grained clastics. This widespread marine transgression has been attributed to rifting along the westernmost part of the miogeocline (Gordey *et al.*, 1987) or to contractional deformation (*i.e.*, Antler orogeny; Smith *et al.*, 1993) with both models being supported by thick tongues of westerly derived coarse sediments in western Earn exposures.

Miogeoclinal sedimentation ceased at the end of the Early Jurassic, due the onset of widespread compressional tectonism in response to collision and obduction of oceanic and arc assemblages along the western margin of the miogeocline. This was the second time during the Phanerozoic that a widespread fundamental change in sedimentation took place along the western margin of the North American craton. The first sedimentalogical record of this deformation is preserved along the eastern margin of the Foreland Belt in the form of westerly derived clastics of the Upper Jurassic Passage beds, the upper member of the Fernie Formation. Deformation progressed in pulses, as evidenced by the eastwardly prograding, unconformity bounded, coarse clastic wedges shed from the emerging mountains to the west. These clastic wedges were subsequently deformed by the easterly advancing mountain front which was active until Early Tertiary time, as recorded by thrusted beds of the Paskapoo Formation (McMechan and Thompson, 1991).

Obduction and thickening of the ancestral North American continental crust allowed the lower parts to reach temperatures sufficient to generate magma and produce widespread Cretaceous plutonism within the Selwyn Basin (Gordey and Anderson, 1993). Some of these intrusions led to the formation of important tungsten skarn and molybdenum-tungsten stockwork-skarn deposits, such as Canada Tungsten and Logtung in the Yukon.

An environment of slow sedimentation, coupled with periodic extensional tectonism within the Kechika Trough, led to the formation of sedimentary exhalative deposits at various times. Sedimentary exhalative sulphide deposits of Cambrian, Middle Ordovician, Early Silurian and Late Devonian ages are present within the Kechika Trough and Selwyn Basin (MacIntyre, 1992). The Cambrian, Silurian and Devonian deposits are the most economically significant. Mineralization in the important Anvil district is hosted by fine grained clastics of probable Cambrian age. The most significant Early Silurian occurrences are the Howards Pass deposits within Road River strata of the Selwyn Basin in eastern Yukon. Late Devonian Earn Group deposits include the Cirque (Stronsay), Driftpile Creek, Bear and Mount Alcock deposits of the Kechika Trough, and the Tom and Jason deposits of the Selwyn Basin (Figure 1). Late Devonian occurrences are believed to have formed within sub-basins developed in response to either a Devono-Mississippian rifting event (Gordey *et al.*, 1987) or as a result of flexural extension related to westward foreland loading and deformation (Smith *et al.*, 1993).

CHAPTER 2 LITHOLOGIC UNITS

Layered rocks in the map area range in age from Late Proterozoic to Quaternary (Table 1). They include: Upper Proterozoic to Lower Cambrian(?) siliciclastics, carbonates and volcanics of the Hyland Group; Lower, Middle and Upper(?) Cambrian siliciclastics, carbonates and volcanics; slate, calcareous slate and argillaceous limestone of the Upper Cambrian to Lower Ordovician Kechika Group; siltstone, slate and minor limestone of the Middle Ordovician to Middle Devonian Road River Group; siltstone and slate of the Middle Devonian to Mississippian Earn Group; varicoloured chert of possible Mississippian to Permian age, and Tertiary to Quaternary basalt of the Tuya Formation. In addition to these units of known or presumed stratigraphic position, a package of slate, quartz sandstone and limestone of unknown age is termed the Aeroplane Lake panel. Rocks of the Cassiar Terrane, west of the Northern Rocky Mountain Trench fault, were examined in a very cursory manner and no subdivision will be attempted here.

PROTEROZOIC

CARBONATE AND QUARTZITE (Pcq)

The oldest rocks within the map area are exposed in the Gataga Mountain area. South of Gataga Mountain, in the core of the Gataga Mountain anticline (Figure 10), these rocks comprise a sequence of massive to thickly bedded quartzite, and minor slate to siltstone, up to several hundred metres thick, which apparently lie stratigraphically below the Gataga Volcanics (Photos 4, 5). They are cream to beige-weathering, light grey to grey, massive to thickly bedded quartzites and calcareous quartzite in stratigraphic contact with Gataga Volcanics. The quartzite contains thin interbeds of pale yellowish-green, laminated, possibly tuffaceous slate near its upper contact with the volcanics. The top of the quartzite sequence is marked by a relatively sharp, conformable contact with 2 to 3 metres of similar yellowish-green tuffaceous slate which gives way upward to massive volcanic fragmentals.

In the immediate hangingwall of the Gataga mountain thrust, east and northwest of Gataga mountain, Gataga volcanics sit stratigraphically above several hundred metres of interlayered, massive to thickly bedded limestone, dolomite and quartzite to sandy limestone. East of Gataga mountain, these rocks are exposed in the core of a northeasterly inclined anticline which is cut off to the northwest by the thrust fault (photos 4, 5). These strata were originally correlated with cambrian siliciclastics and carbonates of unit Csc, based on lithologic similarities (Ferri *et al.* 1996a,

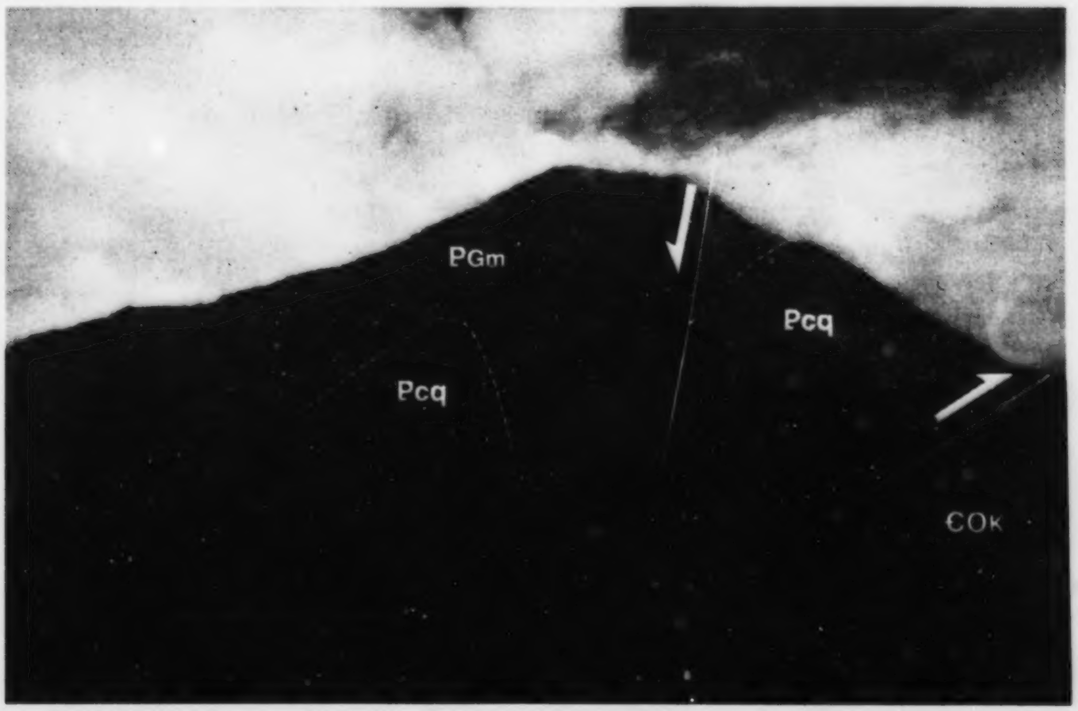
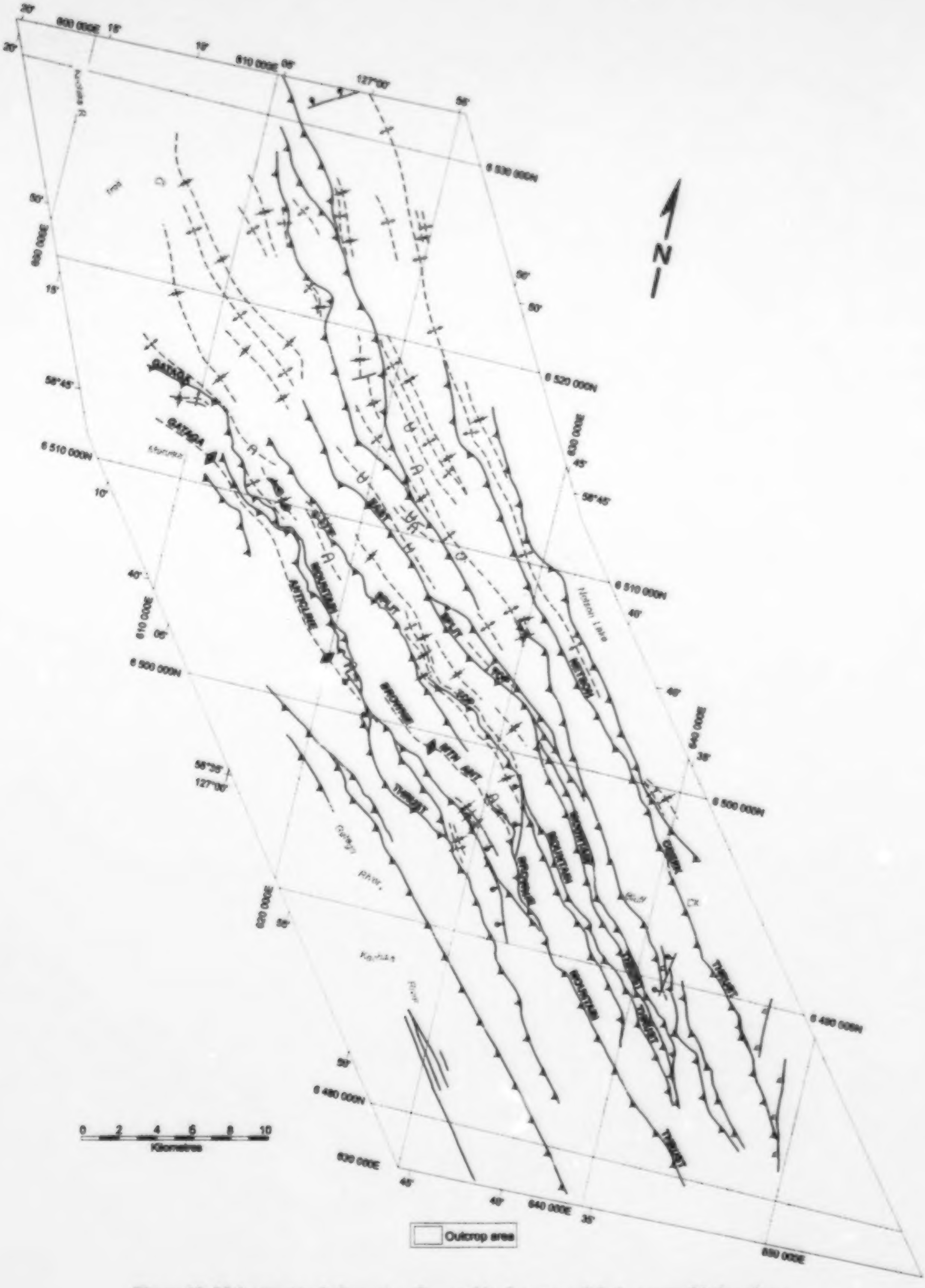


Photo 4. Looking northwest at Gataga Mountain. The siliciclastics and carbonates of unit Pcq can be seen in the core of the Gataga anticline and in the hangingwall of the Gataga thrust fault. These rocks underlie volcanics of unit PGm.

TABLE 1
TABLE OF FORMATIONS

ERA	PERIOD	ROCK UNIT	INFORMAL SUB-UNIT	MAP UNIT	THICKNESS (METRES)	LITHOLOGY
CENOZOIC	Quaternary or Tertiary	Tuya Formation		TQT	?	Fragmental basalt.
CENOZOIC or MESOZOIC	Tertiary or Cretaceous	Other Intrusions		KTp,		Quartz porphyry.
				KTg		Quartz-porphyritic granite to granodiorite.
MESOZOIC	Cretaceous?			Kp		Feldspar and quartz feldspar porphyry dikes.
	Cretaceous	Boya Hill Intrusions		EKp		Sills and dikes of fine to medium crystalline, quartz-biotite-feldspar porphyry and quartz porphyry.
	Late Mississippian to Permian	Mount Christie Formation		MPMC	5	Chert.
PALEOZOIC	Middle Devonian to Early Mississippian	Earn Group		DME	up to 600	Slate, siltstone, chert, minor sandstone, limestone, conglomerate, bedded barite.
	Early Silurian to Middle Devonian	Road River Group	'Silurian siltstone'	SDRR	200-700+	Dolomitic siltstone, slate, limestone chert.
	Early Ordovician to Early Silurian		Lower	OSRR	50-160	Slate, siltstone, argillite, limestone, chert.
	Early Ordovician to Middle Devonian		Kitza Facies	ODRk	?	Carbonaceous calcareous siltstone, silty limestone, siltstone, argillite, slate, sandstone, chert, conglomerate.
	Late Cambrian to Early Silurian	Kechika - Lower Road River gps		COKR	0-100	Slate, siliceous slate.
	Late Cambrian to Early Ordovician	Gabbro		IPg	?	Green, medium to coarsely crystalline gabbro.
		Kechika Group		COK	50-1000	Slate, calcareous slate, limestone.
	Middle to Late Cambrian	Cambrian Carbonate		Cc	0 to 1500	Limestone, dolostone, minor sandstone.
				Ccs	0 to 350	Siltstone, slate, quartz sandstone.
	Middle Cambrian	Conglomerate, limestone		Ccg	250	Polymict conglomerate, minor slate, siltstone and sandstone.
			Maroon Facies	Ccgm	100	Maroon to pink limestone, conglomerate, siltstone, sandstone.
	Early to Late Cambrian	Lower to Upper Cambrian Siliciclastics and Carbonate		Csq	10 to 200	Quartzite.
				Csla	0.1 to 20	Fossiliferous limestone.
				Cslb	1 to 50	Limestone, sandy limestone, quartzite, slate, siltstone.
				Cs	up to 1500	Slate, siltstone, sandstone, minor quartzite, limestone.
	Early to Middle Cambrian	Siliciclastics and Carbonate		Csc	400-700	Quartz sandstone, quartzite, limestone, dolostone.
				Cl	0-200	Limestone, dolostone.
	Early? Cambrian	Quartzite		Cq	200	Quartzite, impure quartzite, quartz sandstone, siltstone, limestone.
	Cambrian to Mississippian	Cassiar Terrane		CA		
PALEOZOIC OR PROTEROZOIC	?	Aeroplane Lake Block		PPal	?	Limestone, phyllite and sandstone.
				PPac	?	Calcareous phyllite and schist.
	Cambrian or Late Proterozoic			PPas	?	Siliceous schist and quartz sandstone.
				CPv	100	Tuff, agglomerate, flows
				CPc	100	Limestone, sandy limestone, minor quartzite
				CPs	500	Slate, siltstone, quartz sandstone, chert and limestone
			Upper Gataga Volcanics	CPv	0 to 200	Mafic volcaniclastics, minor flows.
		Limestone and Sandy Limestone		CPc	100 to 200	Limestone to sandy limestone.
		Slate and Siltstone		CPs	200?	Slate with minor siltstone and sandstone.
		Siltstone, Slate and Sandstone		CPsm	0 to 300	Maroon to grey slate, siltstone and sandstone.
		Limestone		CPl	0 to 200	Limestone, dolomitic limestone.
PALEOZOIC TO PROTEROZOIC	Earliest Cambrian to Late Proterozoic	Hyland Group		CPH	2000	Sandstone, slate, conglomerate, limestone.
PROTEROZOIC	Late Proterozoic	Gataga Volcanics		PGf	0 to 200	Felsic volcaniclastics.
		Quartzite		PGm	0 to 1000	Mafic volcaniclastics, lesser flows.
				Pcq	200	Massive to thickly bedded quartzite, limestone, dolomite, minor slate, siltstone.


20'
600 000E
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10'
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55'
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58°45'
6 510 000N
10'
40'
610 000E
05'
6 500 000N
58°35'
127°00'
620 000E
55'
50'
6 480 000N
630 000E
45'
40'
640 000E
35'
650 000E
6 490 000N
6 500 000N
6 510 000N
6 520 000N
630 000E
45'
58°45'
40'
35'
640 000E
55'
50'
N
0
2
4
6
8
10
Kilometres
Outcrop area
ANTICLINE
THRUST
THRUST
THRUST
THRUST

Figure 10. Main structural elements referenced in the text and their geographic locations.

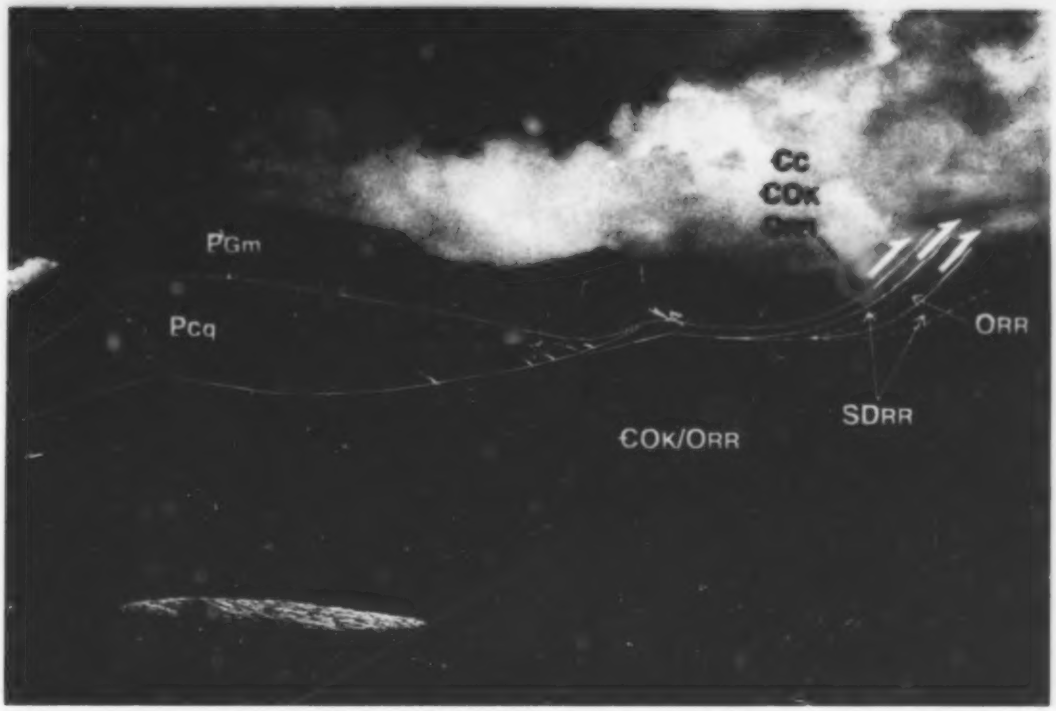


Photo 5. View to the west towards Gataga Mountain. The northeasterly verging anticline shown in Photo 4 is truncated to the east by the Gataga Mountain thrust fault resulting in the disappearance of unit Pcq. Two thin thrust sheets in the footwall of this thrust, to the right, consist of Cambrian carbonate (Cc), together with Road River siltstone and shale (SDRR, OSRR) and Kechika Group calcareous argillite (COK). These thrust slices appear to die out southeastwards into a zone of strongly deformed slates of the Kechika and lower Road River groups. Tightly folded Kechika Group rocks extend into the foreground.

b). Subsequent dating of the Gataga volcanics indicates they are Late Proterozoic in age.

Limestone is light grey to grey, fine grained and contains lenses of orange-weathering dolomite. Dolomite beds are grey and buff-grey weathering. Interlayered quartzite is well bedded to wavy or crosslaminated and may be calcareous or dolomitic. These rocks grade into calcareous or dolomitic quartz sandstone to sandy limestone and dolostone. There are thin interlayers of olive green and maroon siltstone. Stratigraphic top indicators place rocks immediately below the Gataga Volcanics in an upright position. To the northeast, across the core of the anticline, these rocks are overturned where they are in contact with the Gataga Mountain thrust fault.

The upper contact of this panel, with the Gataga Volcanics, appears unremarkable and conformable. Dolostone at the top of the section gives way to several metres of green-grey or blue-grey shaly siltstone with orange-weathering dolostone beds and lenses. This, in turn, grades upward into several metres of wavy to flaggy bedded, interlayered green-grey chert to siliceous siltstone or recrystallized chert and olive green-grey cherty slate with numerous egg-shaped nodules of dolostone. These lithologies pass into 1 to 2 metres of green-grey siltstone and black, paper slate immediately underlying the volcanics. At one of the few localities this contact is accessible, less than half a metre of scree obscures the contact between basal tuffaceous siltstones and tuffs of the Gataga Volcanics and underlying siltstone and black slate. Lithologies on either side of the contact appear undeformed and conformable.

Age and Correlation

The age of these rocks is inferred only from their stratigraphic position below the Upper Proterozoic Gataga Volcanics. The upper part of the volcanics has yielded a 690 Ma U-Pb age (*see* section below). Regional correlations suggest the Gataga Volcanics signal the initiation of Windermere sedimentation in this part of the Cordillera. The conformable nature of the underlying quartzites suggests they are part of the same depositional sequence as the Gataga Volcanics and hence are part of basal Windermere stratigraphy.

Within the Rocky Mountains, a possible correlative to this unit occurs several hundred kilometres along strike to the southwest, in the Deserters Range. Upper Proterozoic rocks in the Deserters Range are assigned to the Misinchinka Group and have been described in detail by Evenchick (1988). The basal part of Misinchinka stratigraphy contains several hundred metres of quartzite which rests nonconformably on 728 Ma age gneissic granite. This is overlain by 400 metres of interlayered quartzite and amphibolite. Evenchick (1988) suggested that the amphibolites represent flows, although the lack of any primary structures or crosscutting relationships does not rule out their emplacement as sill-like bodies. The implied age, lithologic characteristics and intercalation with mafic igneous rocks suggests that basal quartzite of the Misinchinka Group in the Deserters Range may be correlative with quartzite stratigraphically below Gataga Volcanics, in the core of the Gataga Mountain anticline.

Lithologies east of Gataga Mountain suggest a warm, shallow-water shelf environment. Rapid lateral facies changes are evidenced by the disappearance of limestone and dolomite towards the core of the Gataga Mountain anticline. If these sediments, together with the overlying Gataga Volcanics, represent basal Windermere stratigraphy, the implied carbonate shelf environment is in sharp contrast to the documented glacial deposits present within basal Windermere sections in the southern and northern Cordillera (*see* Gabrielse and Campbell, 1991).

This apparent contradiction in depositional regimes raises several questions. One is the placement of carbonate and quartzite, east of Gataga Mountain, stratigraphically below the Gataga Volcanics. Although there is no doubt quartzites occur conformably below the Gataga Volcanics in the core of the Gataga Mountain anticline, the same cannot be said for carbonate and quartzite to the east, where the contact interval is covered by scree. These latter rocks appear very similar to clastics and carbonates of unit Csc, so much so that the units were originally grouped with them in preliminary maps of this area (Ferri *et al.*, 1996). It could be argued that these sediments represent a fault slice of unit Csc and that the scree-covered contact is in fact a fault zone. An argument against this is based upon the apparent upward transition of dolomite and quartzite into finer sediments typical of those at the very base of the volcanics. Furthermore, lithologies on either side of the contact show no evidence of deformation, although a major fault could easily be hidden within these incompetent lithologies.

The Gataga Volcanics have sections of tuff to lapilli tuff with abundant calcite in the matrix, probably of depositional origin. This would lend support to the inference that deposition of these volcanics and underlying sediments occurred in a warm and shallow shelf setting.

There is no disputing the presence of glacial deposits at the base of the windermere in certain parts of the cordillera. Dating of associated igneous rocks at these localities suggests that deposition took place 740 to 780 Ma ago, some 40 to 90 Ma prior to deposition of the Gataga Volcanics and underlying sediments of unit Pcq. Perhaps the most likely explanation is that these sediments and the overlying Gataga Volcanics represent a younger, post-basal windermere volcanic event which occurred during much different depositional conditions; a reasonable possibility considering the time span involved.

GATAGA VOLCANICS

A composite body of bimodal, mafic and felsic volcanic rocks crops out around Gataga Mountain where it forms much of the large, complex, northeasterly overturned Gataga Mountain anticline (Photos 4, 5). The volcanics are subdivided into two packages: a unit of alkalic mafic to intermediate volcaniclastics and flows (PGm) and a sequence of felsic clastic volcanics (PGf). Unit PGf comprises less than 10 per cent of the Gataga Volcanics and is found along the southwestern margin of unit PGm.

Unit PGm

Typically, the volcaniclastics comprise pale to mid-green or greenish grey tuffs (Photo 6). Very fine to medium-grained ash tuff and lithic tuff may be massive and homogeneous, or bedded in units up to about 1 metre thick. Some rocks are more thinly bedded or laminated and were mapped as volcanic wacke or tuffaceous siltstone. Grading is present locally and crossbedding was tentatively identified in some outcrops. Rare lenses of creamy grey chert and calcareous siltstone or tuffaceous limestone are present within the tuffs. At one locality, the base of the volcanics appears to rest on a dolomitic limestone. Here, the first few metres of tuff are micaceous and pale grey rather than the usual green colour, probably due to carbonate and sericitic alteration at the contact.

Volcanic flows, up to tens of metres thick, are subordinate, forming about 25 per cent of the volcanic sequence. They are usually pale to mid-green and very fine to medium grained. Some are vesicular and amygdaloidal, others are finely porphyritic. Dark green spots in some volcanic rocks may be chloritized amygdules or pyroxene phenocrysts. Pillows, pillow breccia and flow breccia are present locally (Photo 7); pillows can be a metre across and many show radiating pipe vesicles and zoning. Preliminary lithogeochemical analysis of the volcanics indicates that they are generally alkalic basalt (Figure 11).

Intermediate to felsic deposits were rarely encountered within unit PGm. On Gataga Mountain, a thin section of flow or crystal tuff of basaltic andesite has textural features suggesting welding. This volcanic sequence is interesting in that it contains phenocrysts of feldspar and 1 to 2 per cent quartz; the latter not typical of rocks with such compositions (Table 2).

One of the most common and distinctive lithologies is a coarse lapilli tuff or agglomerate which underlies large areas on the slopes west of Gataga Mountain. This rock is generally massive and contains rounded to angular fragments in a coarse-grained chloritic or ferrocarbonate clastic matrix (Photo 8). The most common clasts, which are pale green or buff-grey, and very fine grained, are thought to be variably altered volcanic rock, possibly carbonatized or sericitized basaltic lava or tuff, although some material may have originally been more felsic. Some are porphyritic. Less commonly, fragments consist of quartzite and siltstone, or rare limestone. Some clasts are maroon, suggesting partially subaerial sources. The largest clasts are 30 to 40 centimetres across, but most are much smaller. Overall, the deposit is poorly sorted or unsorted. The matrix is grey to green and generally weathers to a grey to rusty orange-brown colour due to the ferroan carbonate in the matrix. The rock is provisionally interpreted as a volcaniclastic (and epiclastic) deposit laid down in a carbonate environment. This is supported by the presence of pods or zones of limestone, orange-brown weathering dolostone and rusty calcareous

Photo 6. Lapilli to agglomeratic tuff of unit PGm. 15 centimetre ruler for scale.

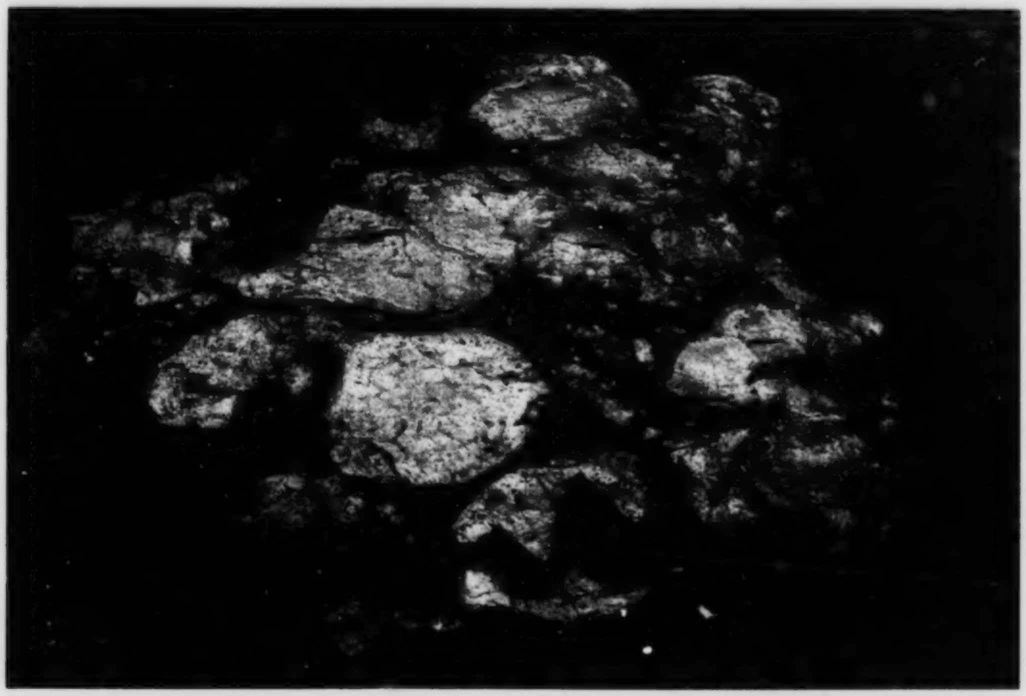


Photo 7. Pillows in volcanics of unit PGm, near Gataga Mountain.

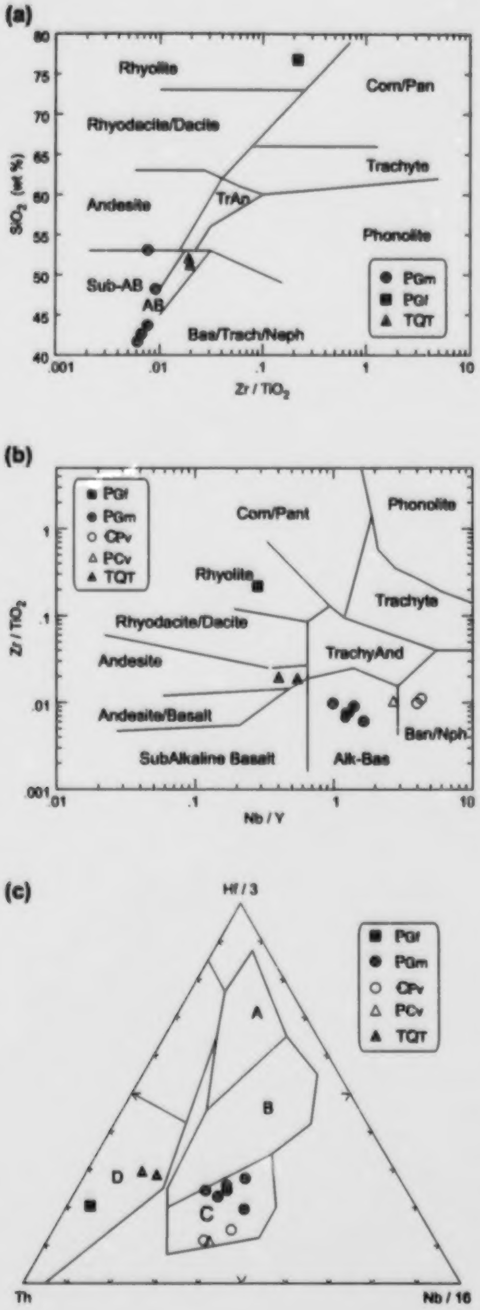


Figure 11. (a) Zr/TiO_2 versus SiO_2 for mafic volcanics of units PGm, PGf and TQT (after Winchester and Floyd, 1977). Samples from units PCv and CPv are too altered to plot on this diagram. Com/Pan: Comendite/Pantellerite; TrAn: Trachyandesite; Bas/Trach/Neph: Basanite/Trachybasanite/Nephelinite; Sub-AB: Sub-alkaline Basalt; AB: Alkali Basalt. (b) Nb/Y versus Zr/TiO_2 for mafic volcanics of units PGm, PGf TQT, PCv and CPv (after Winchester and Floyd, 1977). Note clusters formed by mafic volcanics of PGm and PCv and CPv. Bsn/Nph: Basanite/Nephelinite; Alk-Bas: Alkali Basalt; TrachyAnd: Trachyandesite; Com/Pant: Comendite/Pantellerite. (c) Th-Hf-Nb triangular discrimination diagram from Wood (1980) using data from units PGm, PGf, TQT, PCv and CPv. Fields are: A: N-type MORB; B: E-type MORB and tholeiitic within-plate basalts and differentiates; C: alkaline within-plate basalts and differentiates; D: destructive plate margin basalts and differentiates; dashed line separates tholeiitic island-arc basalts (upper part) from calcalkaline basalts (lower part). Again, note clusters formed by mafic volcanics of PGm and PCv and CPv.

TABLE 2

MAJOR, MINOR, TRACE AND RARE EARTH ELEMENT ANALYSES OF SELECTED VOLCANIC ROCKS FROM UNITS PGm, PGf, ꞒPv, PꞒv AND TQT

MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURES 2 [Section (a)] AND 3 [Section (b)]

	(a)									(b)		
Map No.	1	2	3	4	5	6	9	7	8	1	2	3
Sample	FFE95-1-5-1	FFE95-3-3	FFE95-5-6	FFE95-17-11	CRE95-4-6-3	CRE95-4-6-3A	JN95-9-10	CRE95-16-3-3	CRE95-16-4	FFE96-23-5	FFE96-29-4	CRE96-30-3
Unit	PGf	PGm	PGm	PGm	PGm	PGm	PGm	ꞒPv	ꞒPv	PꞒv	TQT	TQT
Easting	621405	621550	622926	617861	620679	620679	619853	616014	615766	585561	532520	531768
Northing	6499566	6499857	6499867	6504465	6503052	6503052	6502759	6506165	6506117	6565748	6627321	6628095
CaO	1.17	9.42	7.43	7.41	8.66	15.22	4.96	12.83	15.64	17.31	7.79	7.79
K_2O	2.09	0.18	0.90	0.32	0.48	1.77	0.67	1.47	0.03	1.48	2.11	2.17
P_2O_5	0.04	0.45	0.57	0.76	0.32	0.19	0.38	0.60	1.81	0.22	0.74	0.69
SiO_2	76.78	42.62	48.21	41.66	43.71	35.47	53.06	37.25	31.27	29.16	52.07	51.29
Al_2O_3	11.69	11.86	13.36	11.77	13.81	5.99	11.62	10.81	8.16	8.89	16.20	15.98
MgO	0.67	4.02	4.23	5.57	4.94	6.10	4.12	6.24	8.82	7.23	3.93	4.54
Na_2O	2.87	2.98	4.09	3.26	3.51	0.12	2.92	0.17	0.05	0.44	3.00	2.86
Fe_2O_3	1.70	14.22	14.22	13.55	11.59	10.17	9.97	9.99	13.01	6.79	9.82	10.46
TiO_2	0.22	3.66	3.50	3.28	2.40	1.07	3.28	2.81	3.70	0.89	1.75	1.68
MnO	0.02	0.21	0.21	0.22	0.13	0.16	0.22	0.14	0.20	0.15	0.17	0.19
Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.06	0.05	0.01	0.01
LOI	2.31	9.8	2.43	11.93	10.03	23.5	8.52	17.2	16.4	26.81	1.76	1.36
Total	99.65	99.45	99.35	99.76	99.62	99.8	99.79	99.67	99.46	99.31	99.5	99.14
Rb	49	6	19	9	13	41	22	49	5	52	50	52
Sr	38	124	294	73	131	81	59	367	1597	424	601	595
Th	17.1	2.9	4.7	3.2	2.5	1.3	3.8	7.6	14.5	3.5	4.6	4.5
Ba	516	81	1536	177	112	140	510	551	2702	3887	1225	1054
Zr	479	245	318	201	184	105	251	313	365	93	335	330
Y	68.4	39.5	45.1	32.0	25.6	15.9	31.8	25.6	39.2	14.9	39.5	38.9
Nb	19.4	48.0	63.6	53.0	33.5	15.7	39.0	109.3	155.7	40.3	21.7	15.6
La	93.9	26.4	37.7	33.9	16.3	20.3	23.2	61.5	121.8	30.6	47.0	46.2
Ce	205.1	61.6	84.9	75.3	37.7	43.7	54.9	122.4	241.1	55.6	100.1	98.3
Pr	25.0	7.9	10.5	9.6	4.9	5.5	7.0	14.3	28.0	6.1	12.3	11.9
Nd	99.4	34.4	43.7	41.2	21.2	23.0	30.0	55.5	107.1	23.0	49.4	46.6
Sm	21.3	7.9	10.1	8.8	5.0	4.7	6.9	10.2	18.8	4.2	9.6	9.6
Eu	4.0	2.3	3.0	3.1	1.5	1.4	1.9	2.9	5.4	1.3	2.4	2.4
Gd	19.1	8.2	9.8	8.3	5.3	4.3	6.8	8.0	15.0	3.9	8.8	8.7
Tb	3.0	1.3	1.5	1.2	0.8	0.6	1.0	1.1	1.9	0.5	1.3	1.3
Dy	16.8	7.8	9.2	6.5	5.1	3.4	6.3	5.7	9.4	3.1	7.6	7.4
Ho	3.0	1.6	1.8	1.3	1.0	0.6	1.3	1.0	1.6	0.6	1.5	1.5
Er	7.9	4.4	5.2	3.4	2.8	1.7	3.6	2.5	3.8	1.6	4.2	4.0
Tm	1.1	0.6	0.7	0.4	0.4	0.2	0.5	0.3	0.4	0.2	0.8	0.6
Yb	6.5	3.8	4.4	2.7	2.5	1.3	3.1	2.1	2.6	1.4	3.7	3.6
Lu	0.9	0.6	0.6	0.4	0.4	0.2	0.5	0.3	0.4	0.2	0.6	0.6
Hf	14.0	6.7	8.5	4.8	4.8	2.0	6.1	7.1	9.3	2.3	7.1	6.9
Ta	2.5	1.8	2.7	1.9	1.3	0.6	1.7	3.6	4.6	2.1	1.0	0.8

Major oxides, Ba, Rb, Sr, Zr analyzed by x-ray fluorescence at Cominco Laboratories, Vancouver, BC.

REE analyzed by ICP-MS at Analytical Laboratories of Memorial University, St. John's, NF.

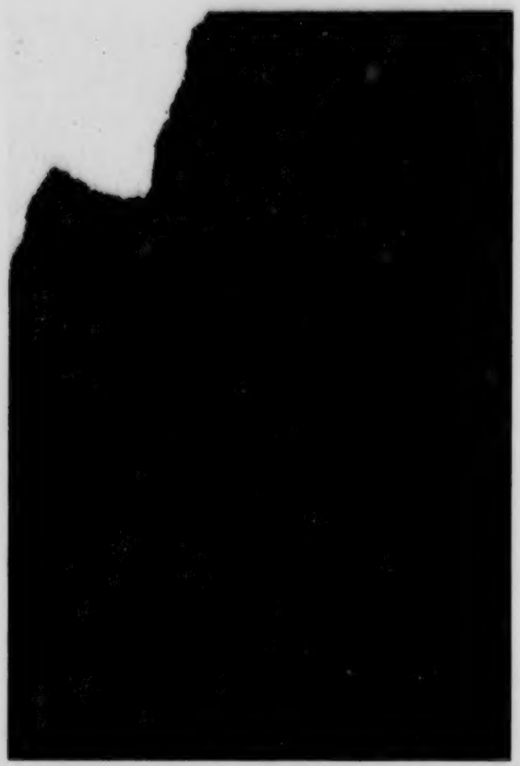


Photo 8. Looking northwest at agglomerate in unit PGm, northwest of Gataga Mountain. Cleavage dips steeply to the southwest.

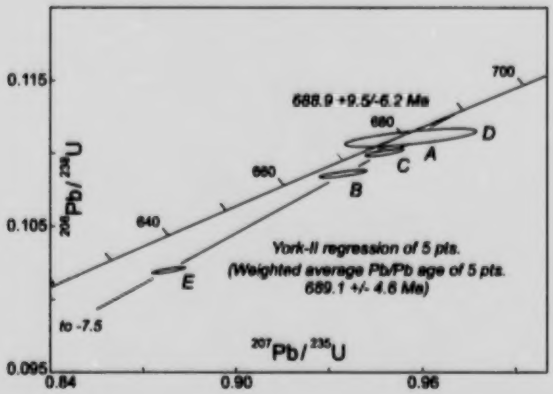


Figure 12. U-Pb concordia diagram showing analyses of zircons from sample FFe95-1-5. Error ellipses shown are two standard deviations. *See* Table 7 for analytical data.

siltstone within the agglomerates, as well as in other parts of the volcanic sequence.

Unit PGf

A mappable body of felsic volcanics, up to 100 metres thick, that occurs a few kilometres southeast of Gataga Mountain, consists of pale grey, sericitic and siliceous, crystal-lithic dacitic or rhyolitic tuff to agglomerate. Phenocrysts are composed of plagioclase and quartz, with the former typically dominating. Locally, abundant calcite and dolomite are found in the matrix and appear to be, in part, primary. Chemical analysis of one sample from this suite indicated a rhyolitic composition (Figure 11). Mafic lithologies along the uppermost section of unit PGm are intercalated with felsic volcanics of unit PGf.

Age and Correlation

Initial mapping in the area tentatively assigned a Devonian and/or Mississippian age to this volcanic suite (Gabrielse, 1962a). These rocks were subsequently thought to be Middle Ordovician in age, based on inferred stratigraphic position and possible correlation with volcanics of known Middle Ordovician age elsewhere in the Rocky Mountains (Gabrielse and Yorath, 1991). Preliminary mapping by Ferri *et al.* (1996a, b) suggested a Cambrian age based on their assumed stratigraphic position below Cambrian siliciclastics and carbonates and above archaeocyathid-bearing limestones. Subsequent U-Pb age dating of the Gataga Volcanics yielded a Late Proterozoic age although it is quite possible that the stratigraphically higher Upper Gataga Volcanics are Middle Cambrian (*see* below).

Zircons were recovered from felsic volcaniclastics of unit PGf. Five zircon fractions were analyzed and a best-fit regression line through these populations gives an upper intercept of 688.9.5±4.6 Ma (*see* Appendix 1; Figure 12). This Late Proterozoic age indicates they are part of the Windermere succession, although typical Windermere sediments, seen elsewhere within the map area, have been removed by the profound 150 Ma unconformity at the top of the sequence.

The Late Proterozoic age of these volcanics, together with their rift-related geochemical signature, suggests they may be associated with initiation of Windermere sedimentation. Comparison of geochronological ages for igneous activity correlated with the inception of Windermere deposition across the Canadian Cordillera indicates an average age of approximately 750 Ma, some 60 Ma older than the Gataga Volcanics (Figures 13 and 14). The younger age of the Gataga Volcanics suggests it may be a separate event or that rifting was more protracted in this region. Stratigraphic arguments were presented earlier (*see* section on unit Pcq) which suggests these volcanics probably represent a younger tectonic event.

Mafic volcanics are exposed at the base of the Windermere Supergroup at various points along the Canadian Cordillera (Figure 13). In the Coal River map area, Gabrielse and Blusson (1969) describe mafic volcanics similar to the Gataga Voclanics at the base of the Lower Cambrian (Unit 3). Although these authors suggest Coal River volcanic rocks are of Early Cambrian age, due to their resemblance with similar volcanics intercalated with sediments of known Cambrian age and their apparent concordance with overlying Lower Cambrian clastics, the relationship with succeeding sediments may be unconformable, suggesting they could be correlatives with the Gataga Volcanics.

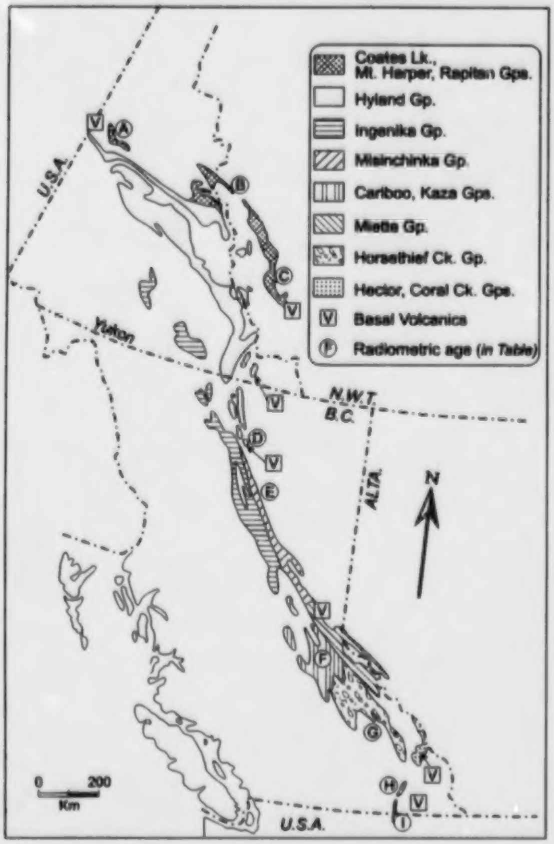


Figure 13. Distribution and subdivision of the Windermere Supergroup along the length of the Canadian Cordillera. Also shown are localities where volcanics occur at the base of the sequence. Letters refer to localities where radiogenic ages were determined for igneous rocks that are assumed to be related to initiation of Windermere sedimentation (corresponding age data presented in Figure 12). Modified from Gabrielse and Campbell, 1991; Mustard and Roots, 1997.

The geochronological age of the Gataga Volcanics, as noted earlier, is younger than the average age of dated igneous activity associated with Windermere basin initiation (Figure 14). Several hundred kilometres to the southwest, in the Deserters Range, amphibolite of possible volcanic origin sits stratigraphically above 200 metres of quartzite which, in turn, rests nonconformably on orthogneiss dated at 728 +9/-7 Ma (Evenchick *et al.*, 1984; Evenchick, 1988). Although the orthogneiss is interpreted to be derived from igneous rocks associated with inception of Windermere sedimentation, the nonconformable nature of the succeeding sediments and volcanics suggests the latter are slightly younger. This, together with the errors on the respective geochronological ages, indicates that the amphibolite (mafic volcanics) in the Desserters Range is about the same age as the Gataga Volcanics. This correlation notwithstanding, *if* the Gataga volcanics correlate with inception of Windermere sedimentation their age indicates that this rifting event must have been a prolonged one (90 Ma) as implied by Evenchick (1988).

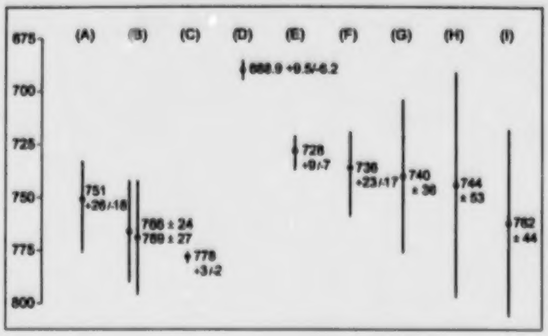


Figure 14. Radiometric age determinations for igneous activity believed to be associated with, or occurring at, initiation of Windermere deposition. Vertical lines are errors associated with each age determination. Modified from Mustard and Roots (1997). Sources are: (A) Mount Harper Volcanic Complex; U-Pb zircon; Roots and Parrish (1988). (B) Diabase sills, Mackenzie Mountains; Rb-Sr whole rock; Armstrong *et al.* (1982). (C) Quartz diorite intrusion, Coates Lake, Mackenzie Mountains; U-Pb zircon; Jefferson and Parrish (1989). (D) Gataga Volcanics, U-Pb zircon; this study. (E) Deserters Range gneissic granite; U-Pb zircon; Evenchick *et al.* (1984, 1988). (F) Hugh Allen gneiss; U-Pb zircon; McDonough and Parrish (1991). (G) Mt. Copeland syenite gneiss, Monashee Complex; U-Pb zircon; Parrish and Scammell (1988). (H) Layered paragneiss, Thor-Odin dome, Monashee Complex; Rb-Sr slab isochron; Duncan (1984). (I) Huckleberry Volcanics; Sm-Nd mineral separate isochron; Devlin *et al.* (1988).

PROTEROZOIC TO LOWER CAMBRIAN

HYLAND GROUP (PCH)

Along the eastern margin of the map area, north of Horneline Creek, sections of grey to brown-weathering sandstone and slate containing distinctive sequences of fine to coarse, gritty, feldspar-bearing, quartz-rich sandstones, conglomerates and lesser slates are found stratigraphically below rocks of Cambrian age (Photo 9, 10). These sedimentary characteristics are similar to Upper Proterozoic sequences seen elsewhere within ancestral North American stratigraphy and suggest these rocks are part of the Windermere Supergroup. In this area, the supergroup is represented by the Upper Proterozoic to Lower Cambrian Hyland Group, as defined by Gordey and Anderson (1993) in the Selwyn Mountains. Regionally, strata of the Hyland Group can be traced from their type locality southward as far as the area around the Gataga River (Gabrielse and Campbell, 1991, pages 127-150).

The Hyland Group, in its type area, has been subdivided into the Yusezyu and Narchilla formations (Gordey and Anderson, 1993). The Yusezyu Formation is dominated by coarse clastics, shale and minor limestone, whereas the Narchilla Formation contains thick sections of shale with lesser siltstone and sandstone. Poor exposure in the present map area does not allow subdivision of the Hyland Group. Lithologies typical of each formation were recognized, al-

Photo 9. Feldspar-bearing grits of the Hyland Group exposed along the ridge containing Tatisno Mountain. The coarse and very immature nature of these sediments suggests they are part of Yusezyu Formation.

though coarse clastics typical of the Yusezyu Formation are by far the most dominant lithologies exposed.

Rocks of probable Proterozoic age were observed in a handful of outcrops along the southwest slopes of the broad valley containing Netson Lake. These exposures consist mainly of grey to green, greasy phyllite with minor thin-bedded, very fine grained sandstone. Lesser interlayered light to dark grey and cream-coloured slate, siltstone (calcareous) and very fine sandstone were also encountered.

North of Horneline Creek, Hyland Group rocks are found along the eastern and western margins of the map area. These rocks were mapped along several creek valleys west of Aeroplane Lake, probably in a thrust panel, and Proterozoic coarse clastics are quite well exposed on the higher peaks and ridges east and northeast of Horneline Creek. The west side of Chee Mountain consists of a large thrust panel of Hyland Group rocks, which continues northwards across Boya Creek. Excellent exposures of Hyland Group gritty sandstones and conglomerates occur on the ridges radiating from Tatisno Mountain in the northern part of the map area. Isolated outcrops of clastics in the Liard Plain to the west, are also thought to be Late Proterozoic in age.

The Hyland Group on Chee Mountain is dominated by grey to olive green or red brown to maroon, well cleaved slate or phyllite to silty slate. Locally, slate forms sections up to several hundred metres thick. Almost as common as these pelitic rocks are thickly bedded to massive, grey-brown weathering, beige to grey quartz-feldspar sandstone to granule conglomerates, which crop out along the top of Chee Mountain and on creeks cutting its western flank. Some quartz grains display an opalescent blue colour, and feldspar constitutes 5 to 15 per cent of the coarser clastics. Sandstone is locally quite impure, approaching a

Photo 10. Feldspar-bearing conglomerate assigned to the Hyland Group, found along the eastern edge of the map area, east of Moose Lake. The roundness of the clasts, together with the lack of significant argillaceous matrix, indicates a cleaner or more reworked sediment than that shown in Photo 9. Width of photo approximately 60 cm.

wacke, with a greenish grey argillaceous matrix. The immature nature of these coarse clastics is also indicated by poor sorting and the subangular to subrounded clasts.

Slaty or phyllitic rocks are generally interbedded with the coarse siliciclastics, in sections from 0.1 to 20 centimetres thick. Some display ball and pillow or flame structures, and others locally contain rip-up clasts of darker slate or siltstone.

Dark grey to brown or orange-brown-weathering, dark grey, finely crystalline, massive to platy limestone up to 20 metres thick forms prominent outcrops along the top of Chee Mountain. It is not known if these exposures represent different horizons or the structural repetition of one section of limestone. The upland immediately northwest of Boya Creek, informally called Boya Hill, is underlain by rocks believed to belong to the Hyland Group, but may include rocks of Cambrian age. Typical grey to orange-weathering, coarse sandstone to granule conglomerate of the Hyland Group outcrops at the southwest end of Boya Hill. Clasts are predominantly quartz with lesser feldspar and mica. These rocks are associated with several ribs of medium to dark grey, massive to platy, sugary limestone and interlayered pale grey to greenish and maroon, massive and well cleaved slate. A large gossanous zone composed of iron carbonate and coarse, cream-coloured calcite and dolomite cuts across slate and limestone.

Southeast of Graveyard Lake, rocks assigned to the Hyland Group are very similar to those along Chee Mountain, except that they lack the distinctive dark grey limestone. They consist mainly of grey, grey-green or green phyllite or slate, with sections of grey to brownish grey, coarse sandstone to granule or pebble conglomerate with characteristic opalescent blue quartz, chalky white feldspar and angular argillite or siltstone clasts. Conglomerate clasts are subangular to subrounded and supported by a finer sandstone matrix. Interlayered with these coarse-grained rocks are massive to crosslaminated white to brownish quartzite, well laminated orange to brown weathering, grey to beige, well cleaved slate and siltstone, and dirty, orange to brown-weathering sandstone. The latter contains minor detrital mica and displays flute casts.

Hyland Group rocks along the upper part of the Red River and west of Aeroplane Lake are very similar to those described above. One difference includes the presence of several intervals of buff to orange-weathering, pale grey to cream, very finely crystalline and platy dolomitic limestone up to 10 metres thick.

Perhaps the best exposures of Hyland rocks in the map area are found on Tatisno Mountain. Interlayered, well cleaved, greenish-grey to grey or tan laminated slate to silty slate and fine-grained brown-weathering sandstone to quartzite predominate. These lithologies are punctuated by massive, tan weathering, beige to white, very coarse sandstone to pebble conglomerate in beds up to 2 metres thick (Photo 9). The clasts consist of angular to subangular quartz (some are polycrystalline with a well developed fabric), white feldspar, grey to dark grey argillite or siltstone, and rare mica. The compositions, angular shape and size of the clasts, together with scouring at the base of many beds, indicates that these are immature, high-energy deposits, most likely derived from an uplifted, steep, source terrain dominated by igneous and metamorphic rocks.

Northwest of Tatisno Mountain, several kilometres south and east of Nancy Lake in the Liard Plain, sparse outcrops of coarse sandstone and conglomerate are tentatively assigned to the Hyland Group. They consist of grey to tan-weathering, grey to cream, massive to thickly bedded, greywacke to conglomerate or breccia. The granule to pebble-sized conglomerate clasts are supported by a coarse to very coarse-grained sandstone to wacke matrix. Clasts are rounded to angular and composed of distinctive green chert, tan to grey or black chert or siliceous argillite, maroon argillite, quartz (locally blue), feldspar and tuffaceous granules.

Age and Correlation

The age of the Hyland Group is latest Proterozoic to Early Cambrian (Gordey and Anderson, 1993). The Yusezyu Formation is entirely Late Proterozoic, whereas the distribution and makeup of trace fossils in the Narchilla Formation suggests that the Precambrian - Cambrian boundary is contained in its upper part (Gordey and Anderson, *op. cit.*, Fritz *et al.*, 1983).

In the map area, assignment of rock packages to the Hyland Group is based primarily on the presence of distinctive coarse, immature, feldspar-bearing quartz clastics and on their stratigraphic position below rocks of Cambrian age. These coarse clastics are in turn associated with distinctive lithologies described from the type locality of the Hyland Group. These include sections of grey, green and maroon slate and dark grey, fine-grained limestone, which are typically found within the upper Hyland Group, particularly in the Narchilla Formation. It is only between Chee Mountain and Boya Hill that all lithologies characteristic of the entire Hyland Group are found, although they could not be confidently assigned to the formation level.

Along the east margin of the map area, and extending up to Tatisno Mountain, all exposed rocks that are assigned to the Hyland Group are probably entirely part of the Yusezyu Formation. In the south, these rocks are succeeded stratigraphically by siliciclastics and minor carbonates of assumed Cambrian age. Although this implies possible removal of the Narchilla Formation, a more probable explanation is that these Cambrian siliciclastics represent lateral or shallower water equivalents of the Narchilla Formation. The Narchilla Formation is known to be laterally equivalent to the Vampire Formation (Gordey and Anderson, 1993; Fritz, 1991) which is very similar to sections of unit Cs found in the map area.

In the Selwyn Mountains, Gordey and Anderson (1993) place the Hyland Group within a basinal or off-shelf setting and imply that these units form the base of the Selwyn Basin. Furthermore, Hyland Group lithologies suggest deposition from sediment gravity-flows and the overall stratigraphic sequence indicates deepening of the basin during Narchilla time (Gordey and Anderson, 1993). These rocks are lateral equivalents of coeval slope and shelf strata which, in the Mackenzie and Selwyn mountains, include the Vampire and Backbone Ranges formations, respectively.

Historically, the coarse, feldspar-bearing clastics of the Hyland Group have been correlated with similar, widespread lithologies of the Windermere Supergroup. This correlation would equate the Hyland Group with the Misinchinka Group of the Northern Rocky Mountains, the Miette Group of the Southern Rocky Mountains and the Ingenika Group of the northern Omineca Belt (Figure 13). Gordey and Anderson (1993) argue that the entire Hyland Group may be Eocambrian and slightly younger than true Windermere grits. Although this may be true for the exposed parts of the Hyland Group in the type locality, the base of the Yusezyu Formation is not seen and could be somewhat older. Geochronology of the Gataga Volcanics indirectly suggests a minimum Late Proterozoic age for the base of the Hyland Group, which is consistent with basal Windermere rocks of the Misinchinka Group further south.

CAMBRIAN OR LATE PROTEROZOIC

Approximately 5 kilometres southeast of Terminus Mountain is found a unit of mafic volcaniclastics that lies stratigraphically above and is spatially associated with the Gataga Volcanics (Figure 2). These volcaniclastics are here informally referred to as the Upper Gataga Volcanics. Originally, these rocks were grouped with the Gataga Volcanics due to their macroscopic and chemical similarities (Ferri *et al.* 1996a, b). The Gataga Volcanics were initially believed to be Cambrian in age due, in part, to the apparent stratigraphic relationships between the Upper Gataga Volcanics and surrounding sediments (Ferri *et al.*, 1996a, b). Subsequent dating of the Gataga Volcanics has shown them to be Late Proterozoic, implying a similar age for the Upper Gataga Volcanics.

If the Upper Gataga Volcanics and Gataga Volcanics represent the same eruptive event, then the relationships seen between the package containing the Upper Gataga Volcanics and surrounding units of known Cambrian age are complicated by faulting. Alternatively, the Upper Gataga Volcanics may be the product of a separate, younger volcanic event. This would indicate the presence of a profound unconformity between the two volcanic packages of some 150 Ma. Furthermore, the alkalic nature of these volcanics would indicate a Cambrian extensional event. This interpretation is supported regionally, and within the map area, by Cambrian age sedimentary deposits most likely related to extensional tectonism (unit Ccg; Taylor *et al.*, 1979; Fritz, 1979; Gabrielse and Yorath, 1991).

In summary, there is stratigraphic evidence to suggest that the Upper Gataga Volcanics are Cambrian. Yet a Late Proterozoic age is also suggested by their chemical similarity and close spatial association with the Gataga Volcanics. As such, a provisional Cambrian or Proterozoic age is suggested for these volcanics and associated units until more information is obtained which establishes their age unequivocally.

Similar complexities are encountered when assigning a stratigraphic age to siliciclastics, carbonates and minor volcanics along Boya Hill. These rocks bear similarities to both Cambrian and Late Proterozoic sequences within the map area.

GATAGA MOUNTAIN AREA

Limestone (CPl)

A few hundred metres of buff to grey-cream weathering, grey platy to massive limestone to dolomitic limestone cap the northwestern, down-plunge termination of the Gataga Volcanics. It is cut off on the northeast side of the Gataga Mountain anticline by the Gataga Mountain thrust. On the western limb of the anticline it thins southeastward until it is unmappable at the present scale, although a thin carbonate up to 10 metres thick is sometime encountered between unit CPsm and the Gataga Volcanics. The limestone is typically well bedded and laminated to crosslaminated. It contains lenses of grey chert or beds of maroon and/or green to grey slate, siltstone or very fine sandstone as in unit CPsm. It is also interlayered with lithologies of unit CPsm at its upper contact.

Siltstone, Slate and Sandstone (CPsm)

Massive to thinly bedded maroon or grey-green to grey slate, siltstone or very fine laminated sandstone conformably overlie limestone of CPl. Lithologies are typically maroon in colour, although the unit commonly contains sections of interlayered green and grey slate to siltstone or very fine sandstone (Photo 11). Malachite staining was seen at one locality. The unit thins and disappears on the eastern limb of the Gataga Mountain anticline. It also disappears, together with the Upper Gataga Volcanics, northeastwards within the core of the anticline. It is believed this is a facies relationship whereby lithologies of unit CPsm are replaced by those of unit CPs. On the northeast limb of the anticline, unit CPsm is assumed to be cut off, together with CPv, by the Gataga Mountain thrust fault.

Slate and Siltstone (CPs)

A package of slate with minor siltstone and sandstone is exposed north of the eastern extension of the Upper Gataga Volcanics, across a syncline cored by carbonate of unit CPc. This sequence is composed primarily of grey to rusty brown weathering, grey to greenish grey slate and banded slate with rare thin lenses or laminae of light grey quartz sandstone to coarse siltstone with micaceous partings. These lithologies appear to grade upward into carbonate of CPc. They can be traced northwestward where they are believed to underlie lithologies of unit Csc.

Limestone and Sandy Limestone (CPc)

Several hundred metres of massive, cream-weathering, grey limestone to sandy limestone and minor dolomitic limestone occur in the core of a syncline at the northern limit of the Gataga Volcanics. At the base, this carbonate section is locally composed of buff to orange-weathering, platy to flaggy limestone. Local thin layers of green slate and sections of thin-bedded grey to grey-brown quartzite and calcareous quartzite also occur, as well as algal-like structures at the south end of its exposure.

Photo 11. Maroon slate and siltstone of unit ЄPsm in the core of the Gataga Mountain antilcine, approximately 8 kilometres southeast of Terminus Mountain.

Upper Gataga Volcanics (ЄPv)

Stratigraphically above the Gataga Volcanics, and separated from them by several hundred metres of limestone and fine siliciclastics of units ЄPsm and ЄPl, are mafic volcanics with similar textural and chemical characteristics. These rocks also interfinger with siliciclastics and carbonates of units ЄPl, ЄPsm and ЄPs, which bear strong similarities to lithologies of known Early and Middle Cambrian age found elsewhere in the map area.

The volcanics on the west flank of the Gataga Mountain anticline, some 10 kilometres northwest of Gataga Mountain, are probably only a few hundred metres thick. The best exposures are along the higher ridges and in creek valleys cutting the section. The volcanics consists of light green to buff or brown-weathering, green volcaniclastics and dark green, massive basalt. Volcaniclastics are dominated by massive to laminated crystal and crystal-lithic tuffs which are interlayered with lesser lapilli tuff and volcanic breccia. Larger volcanic clasts are composed of green aphanitic to amygdaloidal basalt. The volcaniclastics are locally calcareous and interbedded with grey micritic limestone. Dark green, aphanitic to finely porphyritic (pyroxene?) and commonly amygdaloidal basalt forms sections several metres thick. The northern termination of this unit consists of fine to medium-grained gabbro(?) together with volcaniclastics which locally interfinger with maroon and green slates of unit ЄPsm.

Only two geochemical analyses were obtained from volcanics of this unit (Table 2). Classification of these volcanics based on major elements is questionable due to sea floor alteration and metamorphism. Although classification schemes based on less immobile trace elements indicate the volcanics, as with the Gataga Volcanics, are alkaline, they also suggest they are somewhat more so, being of basanite or nephelinite composition (Figure 11).

Age and Correlation of Units ЄPl, ЄPsm, ЄPs, ЄPc and ЄPv

The relationship between limestone of ЄPl and the underlying Gataga Volcanics is not known. This limestone is interlayered with lithologies of unit ЄPsm which is inferred to be either Cambrian or Late Proterozoic in age. Maroon and green slate, typical of ЄPsm, are interlayered with thin beds of volcanics near the northern termination of unit ЄPv. These two units are assumed to terminate against an inferred thrust fault. This fault was not observed, but is required in order to accommodate the map configuration which has the Upper Gataga Volcanics apparently sitting stratigraphically above archaeocyathid-bearing limestones of unit Єsc. Northwestward, along the hangingwall of the inferred thrust, which carries units CPsm and CPv, distinctive maroon clastics and carbonates of Ccgm are exposed stratigraphically above unit Cl. These maroon sediments would be on strike with unit CPsm if not for the inferred thrust fault.

Lithologically, rocks of CPs are very similar to sections of Cs siliciclastics seen elsewhere in the map area. At the north end of the syncline cored by unit CPc, slates of CPs appear to grade into grey or grey-brown quartzite and calcareous quartzite, which in turn pass upwards into carbonate and sandy carbonate of CPc. At this locality, these same quartzites sit stratigraphically above volcanics of CPv. Mapping indicates that lithologies of CPsm, together with those of CPv, lens-out into those of CPs along the core of the syncline containing unit CPc. Furthermore, rocks of CPc bear strong resemblance to Cambrian carbonate sequences of either Csc or Cc.

In summary, the age of the Upper Gataga Volcanics, and for that matter the other units discussed in this section, is equivocal. Associating these volcanics directly with the Gataga Volcanics would require a Late Proterozoic age. Yet stratigraphic relationships between these volcanics, and sedimentary sequences above and below them, suggest a Cambrian age. Correlation of unit CPsm with conglomerate and maroon rocks of unit Ccgm would be appealing and consistent with tectonic environments suggested by each group of rocks. Coarse clastic rocks of Ccgm, together with rapid facies changes of associated units (*see* section on Ccgm; Figure 15), indicate block faulting, probably related to extensional tectonism. Alkalic volcanism of the Upper Gataga Volcanics would be entirely compatible with this scenario.

If these rocks are Cambrian in age, correlatives may be found in the nearby Coal River sheet. Several possibilities are documented, with the thickest consisting of over 125 metres of green, fine grained vesicular volcanics flows and breccias which underlie sandy dolomite of Early Cambrian age (Gabrielse and Blusson, 1969).

BOYA HILL

Rocks along the main part of Boya Hill are variously hornfelsed, hydrothermally altered and mineralized. These siliciclastics and carbonates share similarities with both Cambrian and Upper Proterozoic sequences. The correlation of these sediments is further complicated by the presence of interbedded alkalic volcanics which may be equivalent to either the Gataga or Upper Gataga volcanics, the latter believed to be Cambrian in age. As such, these rocks are given a provisional Proterozoic or Cambrian age

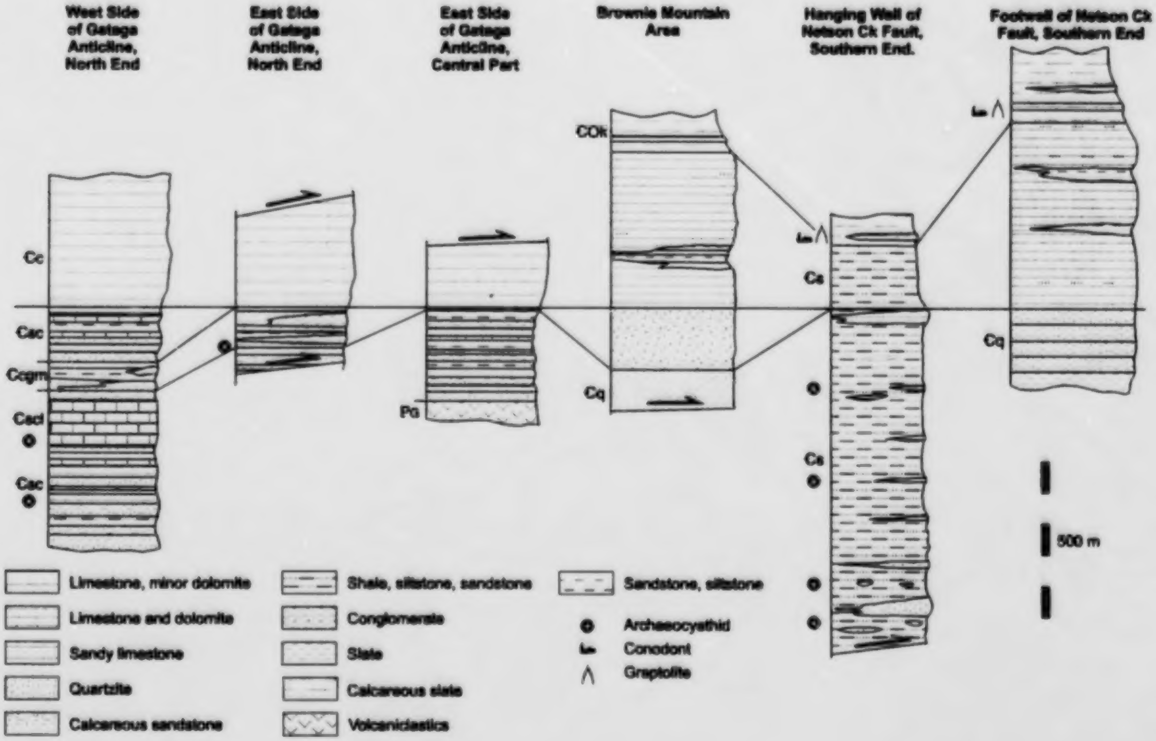

West Side of Gataga Anticline, North End
East Side of Gataga Anticline, North End
East Side of Gataga Anticline, Central Part
Brownie Mountain Area
Hanging Wall of Netson Ck Fault, Southern End.
Footwall of Netson Ck Fault, Southern End
Cc
Cac
Ccgm
Cacl
Cac
PG
COk
Cq
Cs
Cs
Cq
500 m
Limestone, minor dolomite
Limestone and dolomite
Sandy limestone
Quartzite
Calcareous sandstone
Shale, siltstone, sandstone
Conglomerate
Slate
Calcareous slate
Volcaniclastics
Sandstone, siltstone
Archaeocyathid
Conodont
Graptolite

Figure 15. Correlation of various Cambrian units in the southern part of the map area.

until further information is gathered which will conclusively assign a stratigraphic position.

The sequence on Boya Hill has been subdivided into three units; a lower succession of siliciclastics and minor carbonates (PCs) and a succeeding section of carbonate (PCc). Volcanics of unit PCv form lenses within sediments of PCs.

Unit PCc

This unit is quite monotonous and consists primarily of grey, massive to thickly bedded, equigranular, medium-grained crystalline limestone or sandy limestone. It forms the most prominent exposures along the top of the ridge. It is extensively recrystallized to marble near small felsic intrusions and is massive to thinly bedded and medium to coarsely crystalline. Marble locally contains bands of green to pink calcsilicate skarn, in places cut by sulphide veins. Carbonate grades into limy sandstone along the eastern part of the ridge where sandy horizons stand out as resistive ribs within limestone or marble.

Unit PCs

These rocks are well exposed on the southwest-facing slopes and consist primarily of interlayered brown-weathering, grey to dark grey slate, slaty siltstone to fine quartz sandstone or greywacke, pale to medium grey chert and limestone (Photo 12). Limestone forms discontinuous beds or lenses up to 10 centimetres thick. Laminated grey chert and fine-grained limestone locally form conspicuous well bedded, regularly intercalated sequences.

Exposures on the northwest-facing slopes of Boya Hill include interlayered laminated to crosslaminated quartz sandstone, siltstone and slaty siltstone; chert; interlayered chert and quartz sandstone or quartzite; and recrystallized limestone.

Unit PCv

The thickest section of volcanics is found southwest of the Main Face where they form a structurally offset unit several hundred metres thick. These are interpreted to join with thin horizons of volcanics along the Main Face, although the latter may constitute a separate horizon or lens. Typically they are buff to orange-brown weathering, green to brown tuff and lapilli tuff. Clasts consist of feldspar(?) crystals and feldspar porphyry. The rock is very calcareous, suggesting intense alteration; in thin section it is evident that the original clastic components have been pseudomorphed by calcite and quartz. Peatfield (1979a) and Moreton (1984) also describe agglomerates, amygdaloidal flows and intermixed slates and chert in the area.

Chemical analysis is limited to one sample which indicates these rocks were originally alkalic mafic volcanics (Figure 11).

Correlations of Units PCs, PCc *and* PCv

The general stratigraphic or structural order put forward by Peatfield (1979a) is supported by our mapping. It places the coarser siliciclastic rocks at the base of the section, followed by an interlayered limestone, slate and chert package, which also contains the volcanic subunit. Thick to massive limestone and slate comprise the top of the section. Sandy limestone at the summit of Boya Hill is similar to known Cambrian limestone mapped farther south, although the interlayered chert seen in several localities is not typical of Cambrian sections and may be related to hornfelsing.

The chemistry and overall character of PCv volcanics are similar to those on Gataga Mountain, suggesting a direct correlation. Furthermore, chemical discrimination diagrams in Figure 11 show that the single analysis from these volcanics plots with the weakly defined cluster delineated by data from the Upper Gataga Volcanics. The age of the Gataga Volcanics has been accurately determined as Late Proterozoic (690 Ma), whereas the age of the Upper Gataga Volcanics is equivocal. There is evidence suggesting these latter volcanics are Cambrian (*see* Section on Upper Gataga Volcanics). This then implies that sediments enclosing unit PCv are, in part or entirely, Late Proterozoic or Cambrian in age. Lithologies of unit PCs bear some resemblance to sandy carbonate and quartzite below the Gataga Volcanics at the base of Gataga Mountain, though the latter forms thicker, more massive beds.

In conclusion, although lithologies along the main part of Boya Hill are entirely consistent with those of Cambrian units elsewhere within the map area, the presence of alkalic mafic volcanics suggests that these sediments may be in part or entirely of Late Proterozoic age.

Photo 12. Thinly interbedded grey limestone, siltstone and chert of unit PCs found on the east side of Boya Hill (Main Face area).

UPPER PROTEROZOIC AND/OR LOWER PALEOZOIC?

AEROPLANE LAKE PANEL

The term 'Aeroplane Lake panel' was first proposed for a suite of rocks found primarily along the ridge tops between Aeroplane Lake and the Kechika River (Ferri *et al.*, 1997a, b). Very little has been added to our understanding of these rocks since we first described them; the initial description of these rocks is still applicable and is presented in the following paragraphs.

Low-grade metamorphic rocks underlying the highland east of Aeroplane Lake and extending down through the lower parts of Davie Creek and toward the Turnagain River are of unknown affinity. Compositionally, some sections bear a strong resemblance to the Kechika Group, and others to clastics and carbonates of Cambrian and Proterozoic age, respectively. In some places these lithologies occur along strike or are intermixed with each other, precluding a simple assignment. Their stratigraphic placement is further complicated by metamorphic recrystallization that has masked primary features in some areas, and by the presence of a second phase of deformation that is not generally seen elsewhere in the map area. The presence of these elevated metamorphic conditions, in conjunction with polyphase deformation, indirectly suggests deeper stratigraphic levels, although younger stratigraphy could also have similarly affected by way of tectonic burial during deformation. The panel has been divided into three packages: 1) calcareous phyllite and schist; 2) siliceous schist and quartz sandstone; 3) limestone, phyllite and sandstone.

Calcareous Phyllite and Schist (PPac)

Crenulated, finely laminated to banded calcareous phyllites and graphitic phyllites, which locally approach schists in texture, are exposed along the lower part of Davie Creek. Phyllite and schist are thinly interlayered with silty limestone which is locally recrystallized to marble. These higher grade, crenulated rocks continue northwestward into the ridge east of Aeroplane Lake where lower grade, thinly interlayered slate, calcareous slate and grey limestone, very similar to the Kechika Group, are exposed. Directly east of Aeroplane Lake, these calcareous rocks pass along strike into grey to greenish grey phyllites, interlayered with sandy phyllites or with thin laminae of quartz sandstone (Photo 13).

On the eastern slope of this ridge, siliciclastics consist of interlayered dark grey to grey, banded, crenulated graphitic slate, calcareous slate, siltstone, and greenish grey, micaceous quartz sandstone, some of which is feldspathic. Sections up to 10 metres thick of beige to brown-weathering dark grey, finely crystalline, platy to massive limestone with thin phyllite partings occur within the siliciclastics. However, overall this package is much less calcareous than sections to the west.

SILICEOUS SCHIST AND QUARTZ SANDSTONE (PPas)

Dark grey to grey, crenulated phyllite to schist crops out along the lower part of Davie Creek. These rocks are found immediately along strike with brown-grey to blue-grey weathering, silvery grey slate and phyllite, that is interlayered with micaceous quartz sandstone, wacke and siltstone. Siltstone may be graphitic and is interlayered with dark grey, platy limestone. Sections on Davie Creek texturally approach a schist and contain small porphyroblasts of biotite and a carbonate mineral (ankerite?).

Limestone, Phyllite and Sandstone (PPal)

Limestone is the dominant rock type in this unit of the Aeroplane Lake panel. It crops out along the southern crest of the ridge east of the lake, where it forms sections up to 15 metres thick. It is a coarsely crystalline marble, strongly mottled, and contains small phlogopite crystals (Photo 14). Minor pelitic horizons are now composed of crenulated muscovite-chlorite schist and greenish grey calcsilicate. These rocks can be traced into areas of less metamorphosed grey to dark grey, massive to platy limestone with thin phyllite partings. Well layered platy limestone is commonly strongly deformed, displaying several phases of deformation including an early layer-parallel fabric with associated

Photo 13. Noncalcareous carbonaceous to micaceous phyllite belonging to unit PPac (Aeroplane Lake panel) east of Aeroplane Lake.

Photo 14. Late upright folds formed within interbedded limestone and argillaceous limestone of unit **PPal** east of Twin Island Lake (Aeroplane Lake panel).

small intrafolial folds, and a later series of upright folds. Sections of dark bluish grey micaceous quartz-feldspar sandstone to granule conglomerate are found associated with these calcareous rocks.

Age and Correlation

As mentioned above, these rocks, particularly unit **PPac**, have characteristics similar to those of the Kechika Group and to those of unit **Cs**. Yet the presence of gritty, feldspathic horizons suggest links to the Upper Proterozoic Hyland Group. The limestone of **PPal** does not resemble carbonate in Paleozoic units. However, lower grade sections are similar to carbonate of the Hyland Group on Chee Mountain. A similar limestone member is found at the top of the Yusezyu Formation, at its contact with the Narchilla Formation, in the type area of the Hyland Group (Gordey and Anderson, 1993). Although this correlation may be appealing, the calcareous phyllites, and phyllites of **PPac** bear little resemblance to the coarse clastic-rich parts of the Yusezyu Formation, unless this area represents a region which was sheltered from clastic input, a situation alluded to by Gordey and Anderson (*ibid.*) for certain parts of the Yusezyu Formation.

The stronger metamorphism and deformation in this package suggest it may, at one time, have been at greater depth than surrounding rocks, and was later uplifted along a deep-rooted fault. This interpretation implies that these rocks are relatively old, perhaps a lower part of the Hyland Group. In summary, the stratigraphic affinities of the Aeroplane Lake panel are enigmatic due, in large part, to the limited outcrop.

CAMBRIAN STRATA

Strata of Cambrian age show the greatest facies variations within the map area. This is best illustrated by the abrupt, northwestward termination of Middle to Late Cambrian carbonates which give way to fine-grained siliciclastics and minor carbonate assigned to unit **Cs**. A less spectacular facies change also occurs within the dominantly siliciclastic Cambrian section whereby thick sequences of coarser quartz sandstones and quartzites in the southeast are replaced by predominantly shales and siltstones to the northwest. Furthermore, coarse Middle Cambrian conglomerate, and possible volcanic deposits, suggest localized uplift.

Cambrian clastics and carbonates in the area were previously called the Atan Group (Gabrielse *et al.*, 1977; Taylor and Stott, 1973), based on broad similarities with the Lower Cambrian Atan Group in the Cassiar Mountains. The two-fold subdivision of Lower Cambrian strata, as exemplified by the Atan Group in the Cassiar Terrane, is not well developed in rocks of the Kechika Basin. The thick, laterally persistent Lower Cambrian carbonate is missing, or poorly developed, in the Gataga area. Instead, siliciclastics predominate, with only thin layers or lenses of archaeocyathid-bearing limestone. This led Fritz (1980b) to suggest that the term 'Atan Group' be restricted to ancestral North American rocks west of the Northern Rocky Mountain Trench.

The broad similarities of the Lower Cambrian siliciclastic succession to rocks of the Gog Group, as defined in the southern Canadian Cordillera, prompted Fritz (1991) and Ferri *et al.* (1995a; 1996b) to suggest the use of this nomenclature for the Northern Rocky Mountains. Subsequent work by the authors has shown that the term Gog Group is probably not applicable to this part of the Cambrian sequence due to the facies variations and broader age range of the siliciclastics within this package. These siliciclastics, and succeeding carbonates, have broader similarities with Cambrian sequences of the northern ancestral miogeocline, suggesting the use of Selwyn Basin terminology is more appropriate. Poor exposure, coupled with complicated structure, do not allow recognition of a complete section and these units will remain unnamed until more detailed investigations are carried out.

LOWER TO UPPER? CAMBRIAN SILICICLASTICS (Cs)

Fine-grained siliciclastics and minor carbonates of Cambrian age are exposed in several thrust panels within the map area. The best exposures are in the southern part of the area along ridges east and northwest of Split Top Mountain and extending up to Terminus Mountain. Cambrian siliciclastics within the thrust panel east of Split Top Mountain can be traced north until just south of Horneline Creek where they are interpreted as disappearing within the core of a northwesterly plunging anticline. Similar siliciclastics can be traced along the east side of the map area from the area around Horneline Lake northwards to the region east of Gemini Lakes where they are mixed with conglomerate of probable Middle Cambrian age. Good sections of probable Cambrian siliciclastics are also found along creeks draining the eastern and western sides of Chee Mountain. Well exposed sections of possible Cambrian clastics can also be seen along the lower parts of the Red River and along east-flowing creeks south of it and west of the Kechika River.

The thickest and most continuous section of this unit is exposed in the southeastern part of the map area, extending from the Gataga River to the area south of Netson Lake. Structural sections indicate thicknesses of approximately 1200 metres in the north and 1500 metres in the south, assuming no thrust faults or folds have repeated this rather monotonous package. The section consists predominantly of flaggy, thinly interlayered grey-green to dark grey slate, siltstone and brown to beige, fine-grained quartz sandstone (Photo 15, 16). Most sections are dominated by slate and siltstone with thin planar-bedded sandstone commonly making up less than 20 per cent of the section. Slate and siltstone sections commonly have a grey to dark grey, striped or banded pattern and contain layer-parallel worm burrows or other trace fossils (Photo 17). At the southern end of the map area, the basal part of the sequence contains 10 to 30-metre sections of thick-bedded, tan to white quartzite interlayered with lesser, thin-bedded grey to brown siltstone and green to grey phyllite (Photo 18). Some of the thicker sandstone sections exhibit cross-stratification and wave ripples on bedding surfaces. These sequences may form mappable units up to a hundred metres thick (Csq).

In the southern exposure of this panel of Cambrian clastics, approximately 50 to 150 metres of striped or uniform, grey, grey-blue to dark grey to black slate and siltstone are exposed at the top of the section, immediately below the Kechika Group. Immediately north of Bluff Creek, the top of this section contains thin to moderately bedded, grey to orange-weathering grey limestone to sandy limestone, siltstone and black chert layers or nodules.

Cambrian clastic rocks are exposed along the northeast-facing slopes directly south of Netson Lake. Grey and rusty weathering, greenish grey and silvery, banded micaceous slate and siltstone, together with thinly bedded, very fine grained quartz sandstone crop out just northwest of

Photo 15. Thinly interlayered quartz sandstone, siltstone and slate unit Cs in the hangingwall of the Netson Creek thrust, approximately 5 kilometres south of Netson Lake.

Photo 16. Bedding plane picture of quartz sandstone to quartzite of unit Cs, showing ripple structures in an outcrop located 4 kilometres due east of Split Top Mountain.

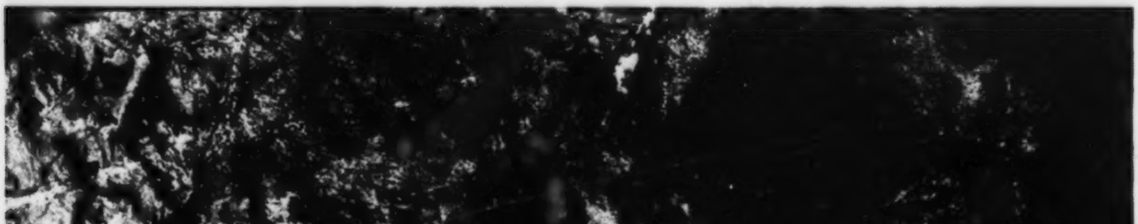


Photo 17. Bedding-parallel worm burrows in siltstone of unit Cs, approximately 5 kilometres southeast of Split Top Mountain.

Photo 18. Moderately to thickly bedded, beige to grey quartzite in the lower part of unit **Cs** east of Split Top Mountain. These rocks become volumetrically important in the lower parts of this unit in the southern part of the map area and, together with unit **Csq**, constitute the main lithology.

the Middle to Upper Cambrian carbonate shale-out in the extreme northeastern part of the map area.

This unit is poorly exposed north and west of Netson Lake, allowing only general descriptions. It is dominated by noncalcareous slate, slaty siltstone and sandstone, with only minor quartzite and limestone. Slate and slaty siltstone are usually medium to dark grey to olive green, and locally have thin colour laminations. The rocks are fine grained, although laminae of paler grey, coarse siltstone or sandstone are quite common. Medium-grained flakes of mica are clearly visible on some cleavage surfaces, which weather a rusty brown colour. These micas, the sandy laminae, and worm trails on some surfaces, are useful in distinguishing these slates from those of younger units in the region.

Sandstone, where present, generally forms intervals or interbeds within the slates. It is pale to dark grey, medium grained, micaceous, locally feldspathic, and usually forms well and thinly bedded (1 to 10 cm) outcrops with flaggy to platy partings. Bedding planes are commonly undulose, suggesting rippled surfaces. Locally, larger bodies or beds of white to grey quartzite or feldspathic quartzite are associated with the sandstones and slates. Rarely, thin beds of oolitic or argillaceous limestone are present.

Southeast of Graveyard Lake, the Cambrian is characterized by well cleaved, thinly interlayered brown to rusty weathering, laminated to banded or mottled, pale to dark grey micaceous slate, siltstone and grey to maroon, very fine sandstone to quartzite. Sandstone and quartzite make up to 30 per cent of the section and beds may reach several metres in thickness. Isolated outcrops of grey-weathering, pale to medium grey, fine to medium crystalline, massive to platy limestone in the southeastern part of the map area are grouped with the Cambrian succession as they are found along strike with siliciclastics of this package.

Cambrian clastics on the south and east sides of Chee Mountain resemble the upper Road River Group, but are generally coarser and contain a larger siliceous component (Photo 19). Assignment of these rocks to the Cambrian is still questionable. They consist predominantly of thinly to thickly interlayered, laminar, orange to brown-weathering, greenish grey, dolomitic to calcareous siltstone and grey to black slate to shale. Siltstone is locally bioturbated, and may form up to 70 per cent of the section. In addition, orange to brown-weathering, grey to dark grey, thick-bedded micaceous sandstone forms sections up to 10 metres thick. Clasts are very fine to fine grained, and composed of quartz and minor dark grey argillite. Sandstone typically shows laminar bedding, and locally it displays low-angle or ripple

Photo 19. Interlayered, orange-weathering, planar laminated siltstone, argillite and minor quartz sandstone found along Chee Mountain and tentatively assigned to unit **Cs**.

Photo 20. Large mass of dark grey to brownish weathering limestone within siliciclastics of unit **Cs** (assigned to subunit **Csla**) exposed east of Split Top Mountain. These limestone lenses typically contain abundant archaeocyathid remains (*see* Photo 21) suggesting they may have been isolated biohermal build-ups. A more regional examination of these bodies indicates they are probably olistostromic in origin (H. Gabrielse, personal communication, 1998).

Photo 21. Cross-sectional view of archaeocyathid within unit **Csla** approximately 5 kilometres south of Netson Lake.

crosslaminations and load casts. Slate locally becomes cherty and may be interlayered with calcareous slate or phyllite.

Although limestone deposits form a minor part of this map unit, they are important in that they imply relationships with Cambrian carbonate sequences found elsewhere in the map area. These carbonate facies may be distal equivalents of the thick Middle and Upper Cambrian carbonates found in other thrust panels. This is supported by the local presence of carbonate debris-flows which may be derived from nearby coeval, thick carbonate buildups.

In the southern part of the map area, the lower half of the succession locally contains discontinuous layers or lenses of brown-grey to pale orange weathering, grey fossiliferous limestone (**Csla**; Photo 20). They range from 10 centimetres to over 20 metres in thickness, can be tens of metres in length and have a rough or rubbly texture in outcrop. These limestone horizons contain abundant archaeocyathid remains (Photo 21) which, together with their lensoidal shape, suggest biohermal buildups. H. Gabrielse (personal communication; 1998) commented that these limestone horizons are well exposed along the highlands south of the Gataga River where relationships suggest they may be, in part or entirely, olistostromic in origin. Two types of limestone are seen in the upper half of the succession: a grey-weathering limestone breccia or conglomerate 1 to 5 metres thick (Photo 22), and a grey, buff to brown or tan-weathering interlayered limestone, sandy limestone to calcareous sandstone and quartzite sequence 1 to 50 metres thick (**Cslb**; *see* also Photo 39). No archaeocyathids were observed in either of these higher limestones. The amount of carbonate in the upper part of **Cs** decreases to the northwest, which mimics the northwestward disappearance of the Middle to Upper Cambrian carbonates in other panels.

The limestone breccia is composed of subrounded and rounded clasts of oolitic and massive limestone, up to 5 centimetres in diameter, and lesser shale clasts in a sandy limestone matrix. Limestone breccia beds grade upward into laminar limestone overlain by calcareous sandstone and quartzite which rarely contain flute casts and scour marks when succeeded by another breccia horizon. These features suggests a debris-flow origin for these deposits.

The limestone and sandy limestone sequences are moderately to thickly bedded with the latter exhibiting cross-stratification. Pure to sandy limestone (up to 30 per cent quartz grains) may contain thin interlayers of quartz sandstone or quartzite, giving the rock a distinctive ribbed appearance. Carbonate breccia horizons and grey to green slate layers are present locally. Up section, these lithologies are immediately succeeded by up to 150 metres of dark grey slate and minor siltstone, and then lithologies of the Kechika Group.

Age and Correlation

Archaeocyathid-bearing limestone bioherms or olistostromes are present within the lower and middle parts of the this unit along the hangingwall of the Netson Creek thrust fault, indicating an Early Cambrian minimum lower age range. There are no fossil localities in the upper part of this section. In the south, dark slates of unit **Cs** appear to pass into overlying slates and calcareous slates of the Kechika Group, suggesting a conformable contact and a Late Cambrian upper age range. Although the lack of Middle and Late Cambrian carbonate below the Kechika Group within panels of unit **Cs** may be the result of an unconformity, its omission is believed to be entirely related to facies transition (*see* section on unit **Cc**).

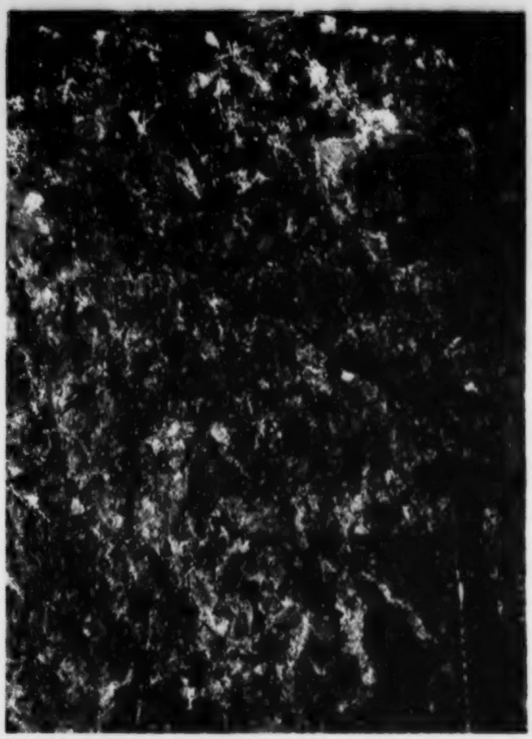


Photo 22. Polymict clast-supported limestone conglomerate or breccia within unit **Cs** several kilometres north of Bluff Creek. This unit is approximately 4 metres thick and clasts consist of grey to light grey massive limestone, dark grey, bedded limestone (locally oolitic), orange-weathering limestone and sandy limestone. The matrix is sandy and the unit grades into surrounding sediments of **Cs**. Several horizons of limestone conglomerate were encountered within siliciclastics of **Cs** on either side of Bluff Creek. Some have flute casts at their base. The significance of these high-energy deposits within the more basinal lithologies of **Cs** is not known.

Carbonate debris-flows and interlayered carbonate and siliciclastics (**Cslb**) suggest possible links to Middle and Upper Cambrian carbonate of unit **Cc** and coarser siliciclastics and carbonate of **Ccs** or **Ccg** in adjacent thrust panels. The interlayered carbonate and siliciclastics of **Cslb** may represent more basinal equivalents of units **Cc** or **Csc**. Archaeocyathid-bearing limestone of possible olistostromic origin (**Csla**) suggests shedding of carbonate material from nearby reefal buildups. Turbidic carbonate deposits in unit **Cs** are also believed to have originated from adjacent carbonate buildups in units **Csc** or **Cc**. This is indirectly supported by the presence of intraformational breccia horizons within Cc along the northern end of the section, southeast of Netson Lake, which could have sourced some of these deposits (*see* Photo 33). In addition, carbonate of Cc interfingers with, and contains, siliciclastic successions similar in composition to those within unit Cs. Some of the turbiditic deposits in Cs contain numerous oolitic carbonate clasts. These were probably derived from Early Cambrian carbonate of unit Csc and its equivalents, as no oolitic limestone was observed in carbonate sections of Cc. Some carbonate conglomerate deposits within Cs are similar to conglomerate assigned to the Middle Cambrian Ccgm unit (compare Photo 22 with photos 29 and 30) suggesting unit Cs may range as young as Middle Cambrian.

Along the east-central part of the Kechika Trough and extending to the west, Fritz (1979, 1991) describes several facies belts within Cambrian strata. There, several hundred metres of Middle and Late Cambrian black slate are shown to be starved basin equivalents of reefal(?) carbonates of similar age. This suggests that the sequence of black slate at the top of unit Cs, and below Kechika sediments, is time equivalent to nearby carbonate of Cc and that siliciclastic and carbonate of unit Cslb has greater affinities with unit Csc (Figure 15).

These arguments suggest that the bulk of unit Cs is time equivalent to unit Csc. It has a higher carbonate component and coarser siliciclastics than Cs, but lithologic similarity of common rock types suggests a link between the two units. This infers a less basinal setting for Csc which is supported by the overlying carbonates of unit Cc.

In the southern Kechika Trough, Cambrian clastics and carbonates have greater affinities with units Csc and Cc, suggesting a more shelf-like setting (*see* McClay *et al.*, 1988; MacIntyre, 1992, 1998; Fritz, 1980a). The basal archaeocyathid-bearing limestone and succeeding shale, siltstone and sandstone of Cs has similarities to the time-equivalent Gull Lake Formation of the central Selwyn Basin (Gordey and Anderson, 1993). H. Gabrielse (personal communication, 1998), in his recent re-compilation of the Kechika River sheet, has also equated similar Cambrian siliciclastics seen elsewhere in the area with the Gull Lake Formation. The upper age range of the Gull Lake Formation is not known, due to a sub-Rabbitkettle (Kechika Group equivalent) unconformity and lack of fossil control, although a Middle to Late Cambrian range cannot be ruled out (Gordey and Anderson, 1993; Fritz, 1991). Most of the Gull Lake Formation is believed to be an off-shelf equivalent to carbonates and clastics of the Sekwi Formation along the Mackenzie Platform. Early Cambrian carbonate buildups are developed within the study area (unit Csc) and regionally (Gabrielse, 1962a, b; Abbott, 1981; Kechika and Rabbit River sheets) and may be the source of Early Cambrian olistostromic(?) deposits at the base of Cs. Gabrielse and Blusson (1969), working in the Coal River sheet, describe slate, siltstone, sandstone and conglomerate of Early Cambrian age along the western part of the area which is equivalent to thick sections of pure orthoquartzite to the east (their unit 4). These western facies may be equivalent to rocks of unit Cs. Farther north, basinal rocks of possible Middle and Upper Cambrian age are represented by shales of Hess River Formation (Cecile, 1982; Fritz, 1991).

North of Horneline Creek, rocks of unit Cs are mapped as sitting stratigraphically above rocks of the Hyland Group which is dominated by lithologies compatible with the Yusezyu Formation. The lack of identifiable sections of Narchilla Formation suggests that it may be represented or replaced by lithologies of unit Cs. The Narchilla Formation has been shown to be laterally equivalent to the Vampire Formation (Fritz, 1991; Gordey and Anderson, 1993). The Vampire Formation consists of dark grey siltstone and shale with interbeds of fine-grained quartz sandstone to quartzite and is similar to sections of unit Cs north of Horneline Creek.

QUARTZITE (Cq)

Thick sections of Cambrian quartzite form several mappable packages in the southern part of the map area. In the southeast, poorly exposed sections of quartzite and lesser carbonate are exposed in thrust panels below the Netson Creek fault. In the far southeastern corner of the map area, thick to massively bedded, brown-weathering, brown to beige quartzite and quartz sandstone are exposed in sections up to 15 metres thick below the Middle Cambrian carbonate sequence (Photo 23). These quartzites and sandstones are sometimes calcareous and commonly show cross-stratification and bioturbation (*Cruziana).*

A well exposed, but strongly folded and faulted sequence of predominantly quartzite is exposed on the east face of Brownie Mountain. Here the section comprises thick to massively bedded grey and brown, impure quartzite, quartz sandstone and white quartzite with lesser grey siltstone and sandy siltstone. The thickness of this section is difficult to determine as it is in the core of an overturned fold which is cut by a thrust fault. A rough estimate is in the order of 200 metres. Sections of quartzite to impure quartzite, from 10 to 30 metres thick, are separated by 10 to 20-metre sections of thin to thick-bedded quartz sandstone and siltstone. The massive to thick-bedded quartzite units show cross-stratification and rare bioturbation in the form of bedding-perpendicular *Skolithus* burrows. The thinner bedded sandstone and siltstone sections commonly contain current ripples and bedding-parallel worm burrows. Less common but conspicuous orange-weathering, cross-stratified limestone to sandy limestone, which locally contains thin interbeds of calcareous sandstone, is found in sections up to several metres thick.

Age and Correlation

These quartzite sections were originally equated with the Gog Group due to similar overall lithologies, associated trace fossils and position below carbonate of inferred Middle to Late Cambrian age (Ferri *et al.* 1995a, b). Although this is reasonable, rapid facies changes within Cambrian strata preclude distinguishing these rocks from other Cambrian units elsewhere in the map area and suggest this terminology is not appropriate. Although we still believe that they are Early Cambrian in age, it is possible that they may, in part or entirely, be related to overlying conglomerate of

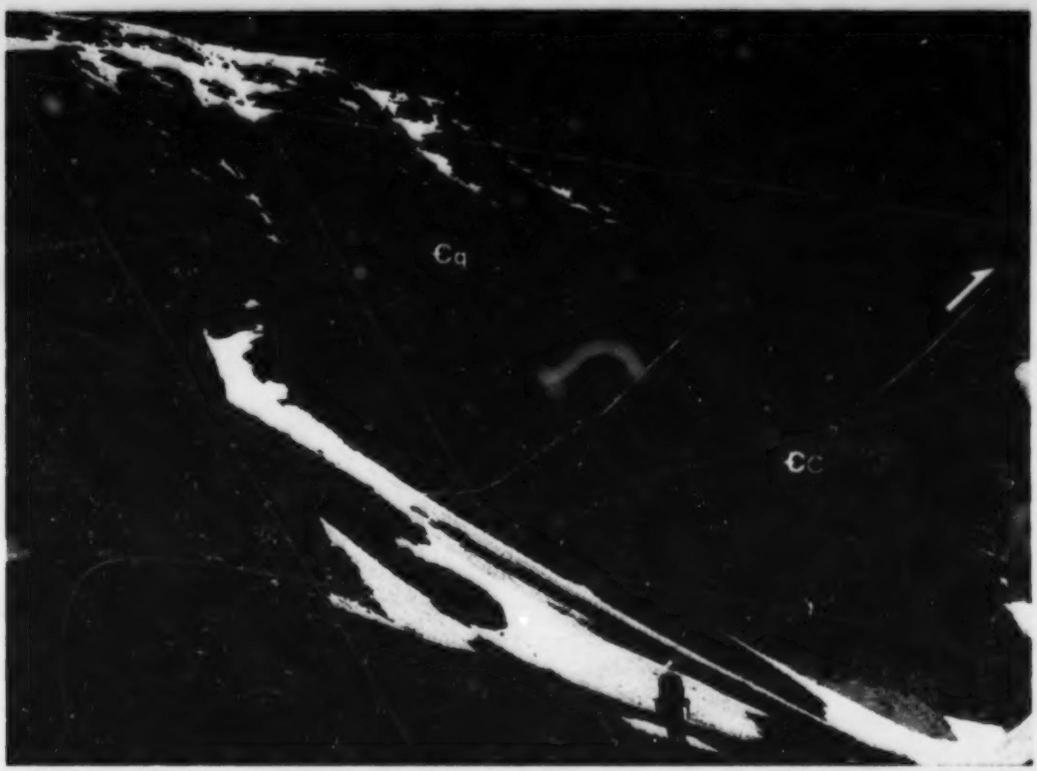


Photo 23. Looking north at the eastern flank of Brownie Mountain. This picture shows quartzite of Cq carried at the base of the Brownie Mountain thrust as it overrides a folded sequence of carbonate of unit Cc. The upper slopes of Brownie Mountain are composed of coarse, massive conglomerate of unit Ccg.

unit Ccg, suggesting they are as young as Middle Cambrian.

Thick sections of quartzite have been described from the southern Kechika Trough by MacIntyre (1992, 1998), McClay *et al.* (1988) and Fritz (1979; 1980a) and are broadly Early to Middle Cambrian in age. Unit Cq may also conceivably correlate with the upper parts of Lower Cambrian quartzite in the Coal River map area (unit 4, Gabrielse and Blusson, 1969) which, in turn, may be correlative with the upper part of the Upper Proterozoic to Lower Cambrian Backbone Ranges Formation further northeast (Gabrielse *et al.*, 1973).

SILICICLASTICS AND CARBONATES (Csc)

A mixed succession of sandstone and quartzite (partly limy), limestone and dolostone, and lesser slate and siltstone (Photo 24) is exposed along the hangingwall of the Gataga Mountain thrust fault, between Gataga and Terminus mountains. Similar rocks are found in the hangingwall of thrust faults southwest of Gataga Mountain. Structural sections suggest thicknesses ranging from 400 to 700 metres. The coarser siliciclastics are generally well bedded on a scale of centimetres to decimetres, and some beds show grading, well developed 'herringbone' crossbedding (Photo 25) and, rarely, ripple marks and trace fossils such as worm trails and burrows. Quartzites and quartz sandstones are pale grey to pink or beige, and are more thickly bedded to massive. They are locally calcareous, especially close to limestone. Intervals of platy limestone to limy sandstone are common, forming beds or a series of beds within the siliciclastics. Slate and siltstone are generally subordinate, comprising thin interbeds in the other rocks.

Northwest of Gataga Mountain, the contact between the Gataga Volcanics and unit Csc is believed to be unconformable and the entire sequence is overturned. Lithologies in Csc become more argillaceous to the northwest and contain thick sections of grey to grey-brown slate, siltstone and fine-grained, grey sandstone. Horizontal worm burrows are sometimes observed within the slate and siltstone sections.

Limestone and Dolostone (Cl)

Near the top of unit Csc are thick limestones and lesser dolostones which are well exposed north and south of Matulka Creek, particularly at the summit of Terminus Mountain. This unit forms sections up to 200 metres thick and is traceable for up to 4 kilometres. The limestone is generally pale to medium grey and buff-grey, very fine to medium grained and more homogeneous and massive than limestone lower in the stratigraphy where limestone is interbedded with the siliciclastics; however, it is not as uniform as the thick Middle to Upper Cambrian carbonates of unit Cc. Bedding is generally indistinct, although locally, where the limestone is sandy and oolitic, or has argillaceous

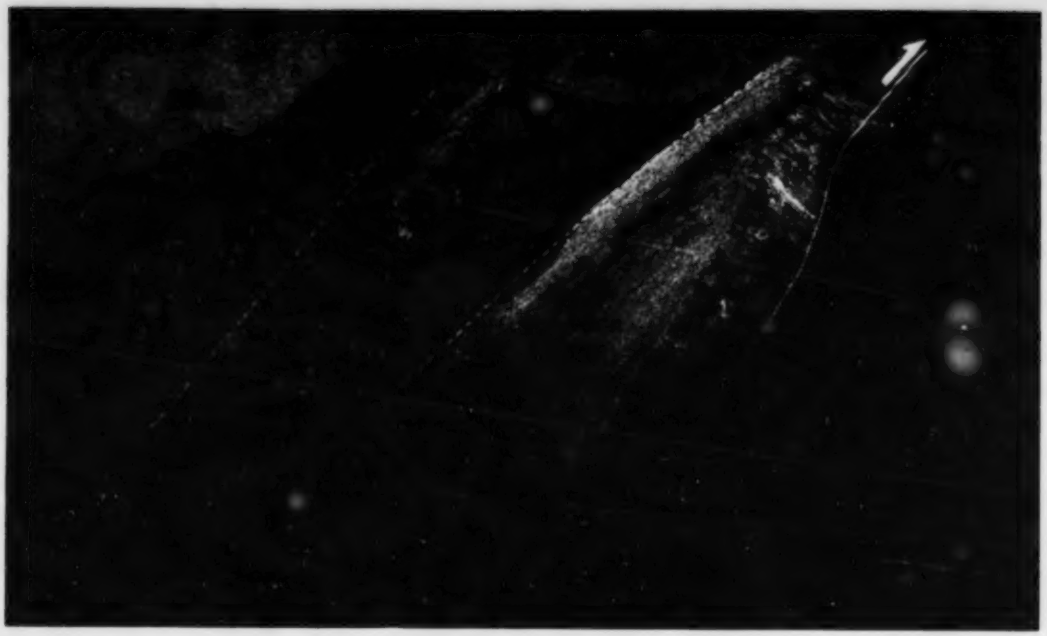


Photo 24. View to the northwest from near Gataga Mountain looking at the eastern overturned limb of the Gataga Mountain anticline. The Gataga Volcanics (PGm) are unconformably overlain by siliciclastics and minor carbonates of unit Csc which are in turn conformably overlain by carbonate of Cc. A very thin quartzite-pebble conglomerate assigned to unit Ccg is found between Csc and Cc.

Photo 25. Herringbone cross-stratification in quartzites of unit Csc, northwest of Gataga Mountain.

laminae, bedding is more clearly defined. Dolostone to sandy dolostone is fairly common and weathers pale orange-brown. A few beds of limestone-rich, dark grey to black oncolites up to 4 centimetres across were noted.

Age and Correlation of Units Csc *and* Cl

North and south of Matulka Creek, archaeocyathids were found in limestone of unit Cl. Archaeocyathids were also seen in carbonate horizons below limestone of Cl, immediately above rocks of unit CPs. The age of these latter sediments is uncertain, but they are believed to be Cambrian and most likely equivalent to unit Cs.

South of Matulka Creek, Middle Cambrian maroon clastics and carbonates of unit Ccg typically sit above those of unit Csc. This is not the case on the east side of the Gataga Mountain anticline where rocks of Ccg appear to thin to the northwest and terminate within lithologies of unit Csc, which, in turn, crop out below Middle and Upper Cambrian carbonates of Cc. The implication of this is that, along the east side of the anticline, the section of Csc that is above Ccg, and extends southeastward along the top of the Upper Gataga and Gataga volcanics, is entirely of Middle Cambrian age. Lithologically these rocks appear similar to the bulk of unit Csc and have been grouped with it. On the east side of the Gataga Mountain anticline, only a few metres of Ccg immediately underlie carbonates of Cc and the entire upper section of Csc has either been removed or not deposited. In summary, unit Csc ranges from Early to Middle Cambrian in age.

Unit Csc was originally part of units 4 and 5c of Gabrielse (1962a). It is time equivalent to parts of unit Cs. Furthermore, finer grained sections of Csc are very similar to lithologies within Cs, suggesting a facies relationship between the two units within the map area (Figure 15). In the southern Kechika Trough, the Early Cambrian is represented by quartzite, siltstone, shale and carbonate assigned to the Gog Group (Fritz, 1991; MacIntyre, 1992, 1998; McClay *et al.*, 1988), very similar to the lower part of unit Csc. Middle Cambrian clastics in the southern Kechika Trough are believed to be related to syn-depositional block faulting and, as a consequence, exhibit extreme facies changes (Fritz, 1991; 1979). Parts of the described sections are broadly similar to the upper parts of Csc. The suggested block faulting in the south may be present within the study area and may explain for the apparent thickness variations of unit Csc across the Gataga anticline.

In the Coal River map area, several hundred metres of limestone, siltstone, sandstone and sandy dolomite to dolomitic sandstone are of Early Cambrian age (units 5 and 6; Gabrielse and Blusson, 1969). These rocks are broadly similar in age and overall composition to rocks of unit Csc. Possible equivalents of Csc further north in the Selwyn Basin include the Early Cambrian Sekwi Formation. The Sekwi Formation is dominated by carbonate rocks, although in northeast-central Selwyn Basin it shows considerable variation and contains thick tongues of coarse to fine clastics (Fritz, 1991).

CONGLOMERATE AND MAROON FACIES (Ccg)

Up to 250 metres of distinctive massive, polymictic granule to boulder conglomerate is exposed in the core of the overturned Brownie Mountain anticline. These rocks plunge northwestward below Middle to Late Cambrian carbonate of unit Cc, re-appear along the banks of a southwestward flowing creek, and then disappear northward below rocks of the Kechika Group. Similar, but much thinner and finer conglomerate is exposed in the hangingwall of the Gataga Mountain thrust, just west of Brownie Mountain. Quartzite, sandstone, dolomite and conglomerate southeast of Brownie Mountain are also provisionally assigned to this unit. One to several hundred metres of distinctive maroon, mixed siliciclastic and carbonate, together with an unusual limestone pebble to cobble conglomerate crops out along the base of unit Cc or within unit Csc north of Gataga Mountain. Although these rocks were originally grouped with either Cc or Csc, it is now believed they are equivalent to conglomerate on Brownie Mountain and therefore have been separated out (see following section on Ccgm).

Conglomerate exposed on Brownie Mountain is massive, brown weathering and brown to grey or green on fresh surfaces (Photos 26, 27). The lower contact of this unit was not observed at Brownie Mountain, but its top appears to grade upward into limestones and dolomites of unit Cc. The conglomerate is polymictic and matrix supported with 30 to 70 per cent subangular to rounded granule to boulder-sized clasts. Clast types include brown to white quartzite (70 per cent), orange, grey or maroon-weathering limestone (10 per cent), dark grey, grey or green slate and siltstone (10 per cent) and green basalt(?), diorite or gabbro (10 per cent; Photo 27). Much of the matrix is green and chloritic, and it is speculated that much of it is tuffaceous, implying that the conglomerate was derived from the erosion of volcanic as well as sedimentary rocks. Grey to brown slate, siltstone and sandstone units up to several metres thick are locally present.

Southeast of Brownie Mountain, interlayered 1 to 2-metre beds of orange, buff to white, planar to cross-stratified quartzite, quartz sandstone and dolomite to sandy dolomite are tentatively assigned to this unit. The upper part of this package contains distinctive layers of quartzite-pebble conglomerate 10 to 20 centimetres thick, with clasts from 3 to 10 centimetres in diameter. Locally, sandy dolomite near the top of these conglomerates contains isolated quartzite cobbles up to 5 centimetres in diameter. The assignment of this package to unit Ccg is based primarily on the presence of conglomerate together with the coarseness and colour of associated siliciclastics.

Maroon Facies (Ccgm)

Between Gataga and Terminus mountains a package of siliciclastics and carbonates, unit Ccgm, is commonly a distinctive maroon colour. This section is also characterized by the presence of one or more horizons of polymictic conglomerate. These rocks were previously noted by Ferri *et al.* (1996a, b) but were grouped with either unit Cc or Csc. Discussions with H. Gabrielse (personal communication,

Photo 26. Massive boulder conglomerate of unit Ccg, found along the ridge containing Brownie Mountain.

Photo 27. Close up of Ccg conglomerate showing its polymictic character, including the presence of mafic igneous clasts of probable volcanic origin. This, together with the green, chloritic matrix, suggests coeval volcanic activity.

1997) on the regional significance of these lithologies has led us to agree that this package is equatable with conglomerate along Brownie Mountain. This is supported by the similarities between certain lithologies and the same stratigraphic position of the two sequences.

These rocks are exposed on both limbs of the Gataga Mountain anticline south of Matulka Creek. Along the south end of the eastern, overturned limb, the unit is only a few metres thick but thickness increases northward to over 100 metres just south of Matulka Creek. The distinctive maroon colour is easily seen along the top of the ridge, where it is at the base of carbonates of unit Cc, and extending northwestward from the northern termination of the Gataga Volcanics to Matulka Creek (Photo 28). Maroon clastics and carbonates also form a section up to 100 metres thick above carbonate of unit Cl along the northern limb of the Gataga Mountain anticline. The thickest and best exposed section of this unit is on the eastern limb of the anticline along the top of the ridge immediately south of Matulka Creek. Its true thickness is difficult to determine due to folding and faulting, but it is at least 100 metres. Stratigraphically, these rocks are found between units Csc and Cc.

The section is characterized by distinctive maroon to pinkish silty limestone to micaceous siltstone up to 15 metres thick, interlayered with equally thick, thin to thickly bedded, grey to light grey to maroon, finely crystalline limestone which locally contains up to 30 per cent subangular grey to maroon chert fragments and quartz grains. It also includes planar to crossbedded, grey to brown, calcareous quartz sandstone to quartzite, with horizons of sandy limestone and micaceous siltstone, also locally maroon in colour. One of the most characteristic lithologies in this section is grey to maroon, massive polymictic conglomerate up to 20 metres thick (Photo 29a, b). Clasts are dominated by grey to white limestone (80 per cent), maroon siltstone and maroon calcareous siltstone to limestone (15 to 20 per cent) and minor black to grey chert (less than 2 per cent). Clasts are well rounded and stretched along the foliation, with the dimensions of the larger clasts being as much as 20 centimetres long by 5 centimetres in diameter. Several conglomerate units were observed and the thickest contain maroon siltstone, sandy limestone and calcareous sandstone layers. Conglomerate is also associated with white to light grey, very finely crystalline limestone with thin to thick layers of maroon siltstone to calcareous siltstone.

This section thins southeastward along the top of the ridge. It is only some 8 metres thick, stratigraphically below unit Cc where it terminates against the Gataga Mountain thrust fault. This unit is found on the northeast-facing slope, just north of the small syncline containing limestone assigned to unit CPl. At this locality, light green matrix-supported conglomerate, up to 4 metres thick, rests stratigraphically below limestone of unit Cc. The colour is imparted by the green, sericitic matrix. Clasts are pebble sized, well rounded and composed of white to beige quartzite (80 per cent) and limestone (20 per cent). Below the conglomerate is equally thick, maroon, sandy limestone with maroon siltstone to slate partings. The limestone contains angular to rounded, cherty red siltstone clasts less than 1 centimetre across. It is followed down section by similar conglomerate and limestone. A green to greyish micaceous sandstone with shale and siltstone partings is exposed below the lower limestone. This gives way to grey to grey-brown siltstone, slate and very fine sandstone typical of unit Cs. Outcrop is lost up slope and the next series of exposures is similar slates, siltstones and sandstones which are part of unit CPs. A possible Proterozoic age is assigned to the latter sediments due to stratigraphic links with the Upper Gataga Volcanics.

To the southeast, rocks of units Csc and Cc re-appear in the hangingwall of the Gataga Mountain thrust. Similar greenish conglomerate, 1 to 3 metres thick, with a sericitic matrix is again exposed between rocks of units Csc and Cc. Quartzite clasts are up to 30 centimetres across and some are composed of the enclosing slates and siltstones of unit Csc. The conglomerate also appears to form lenses within siliciclastics of Csc.

Maroon clastics and carbonates on the southwestern limb of the Gataga Mountain anticline are very similar those

Photo 28. Looking northwest toward Terminus Mountain (in the far distance) along the ridge containing Gataga Mountain. The observer is approximately 8 kilometres northwest of Gataga Mountain. The ridge contains several hundred metres of steep to northeasterly overturned maroon sediments of unit Ccgm exposed along the northeastern limb of the Gataga Mountain Anticline. These can be traced as far north as Terminus Mountain and thin to several metres a few kilometres north of Gataga Mountain.

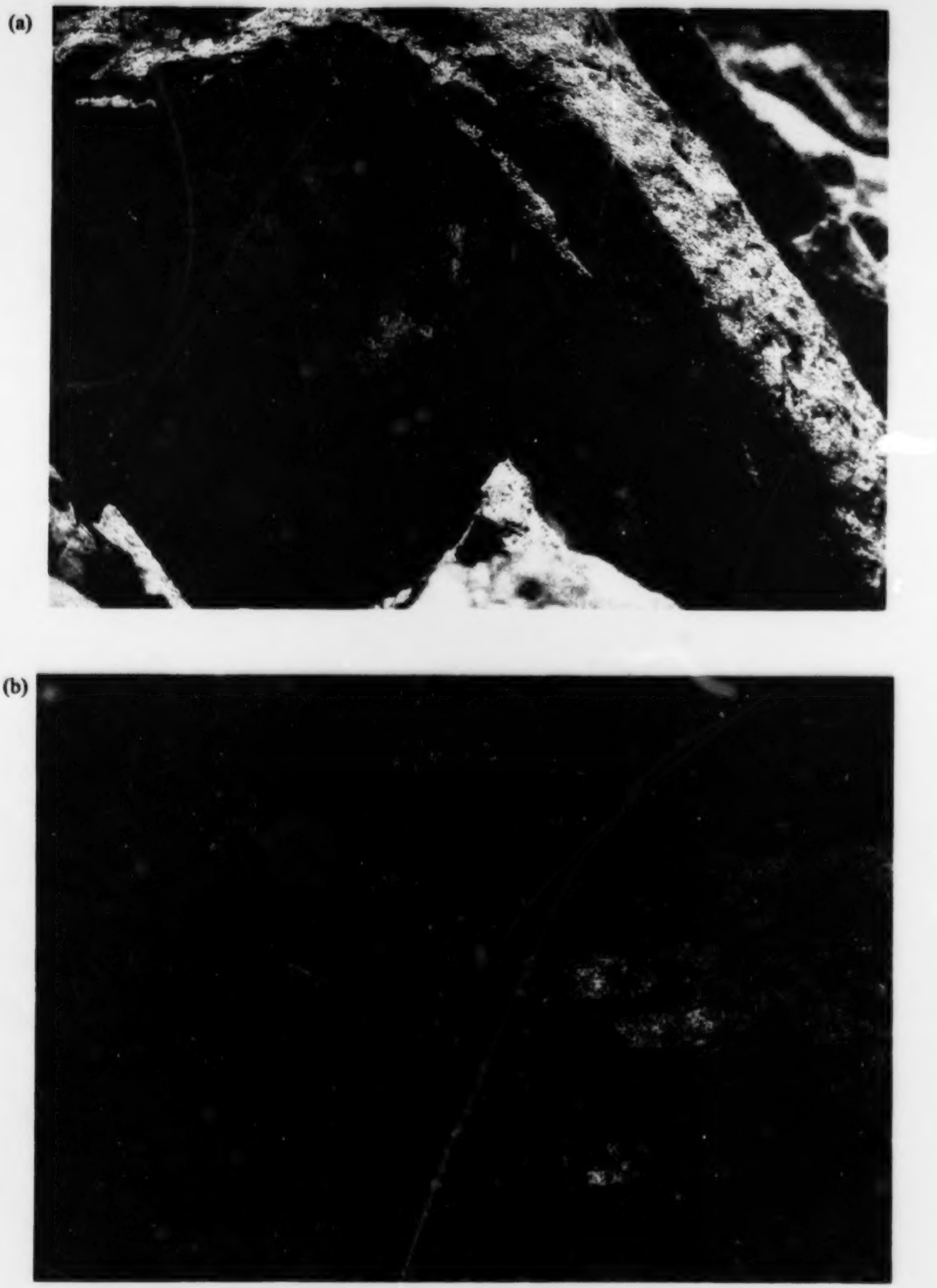


Photo 29. Maroon-coloured, polymict carbonate conglomerate of unit Ccgm, several kilometres southeast of Terminus Mountain. The clasts at this locality are elongate due to plastic deformation. (a) View looking down the long axis of the lineation and (b) perpendicular to the long axis of lineation.

along the northeastern limb. They occur above archaeocyathid limestone assigned to unit Cl. The conglomerate contains well rounded, pebble to cobble-sized clasts of grey or cream-coloured limestone or sandy limestone up to 15 centimetres across, as well as a few pebbles of maroon siltstone or grey-black chert. It is up to 10 metres thick, well sorted and clast supported, with a brownish maroon, sandy carbonate matrix. These rocks pinch out northwestward and disappear into clastics and carbonates of Csc. These maroon rocks, together with the underlying limestone of Cl, were originally correlated with maroon siltstone, slate and limestone of CPsm and CPl into which they can be traced, and which occur stratigraphically below the Upper Gataga Volcanics (Ferri *et al.*, 1996a, b). However subsequent dating of the Gataga Volcanics suggests the Upper Gataga Volcanics may also be Proterozoic in age indicating this interpretation may be invalid and a thrust fault is inferred separating the two sequences until further dating can resolve the problem.

Northeast of Graveyard Lake, a broad, poorly exposed region, is underlain by sandstone, siltstone, conglomerate and slate, believed to be Cambrian in age and tentatively assigned to unit Cs, although other units of Cambrian age or younger may also be represented. These rocks are characterized by massive to thickly bedded, white or grey to maroon or brown calcareous sandstone or wacke to conglomerate, locally approaching 10 metres in thickness. Sand grains are dominated by spherical, vitreous quartz with lesser dark grey chert, argillite, carbonate and rare feldspar. Conglomerate clasts are typically granule to pebble sized, although locally they approach 30 centimetres in diameter (Photo 30). This conglomerate, together with the maroon colour of some of the sandstones, led us to correlate these facies with Ccg. Clast composition is diverse, with varicoloured quartzite (white, red to maroon, grey to dark grey), grey limestone (some of which is oolitic), orange-weathering limestone, white to black chert, sandy limestone, grey siltstone and greenish grey sandstone. Quartzite clasts tend to be rounded but many range to subangular. Clasts are supported by a calcareous quartz sandstone matrix which approaches a sandy limestone in places. These coarser clastics are associated with cream to buff-weathering, blue-grey limestone, red-banded cherty siltstone, olive green chert and cherty argillite and grey slate. Also in this area, thinly interlayered pale to medium grey, laminated and crosslaminated, fine calcareous siltstone to silty limestone and medium to dark grey silty slate may occur near outcrops of the sandstone and conglomerate. These rocks superficially resemble the Kechika Group. Outcrops of orange-weathering, dolomitic siltstone, possibly belonging to

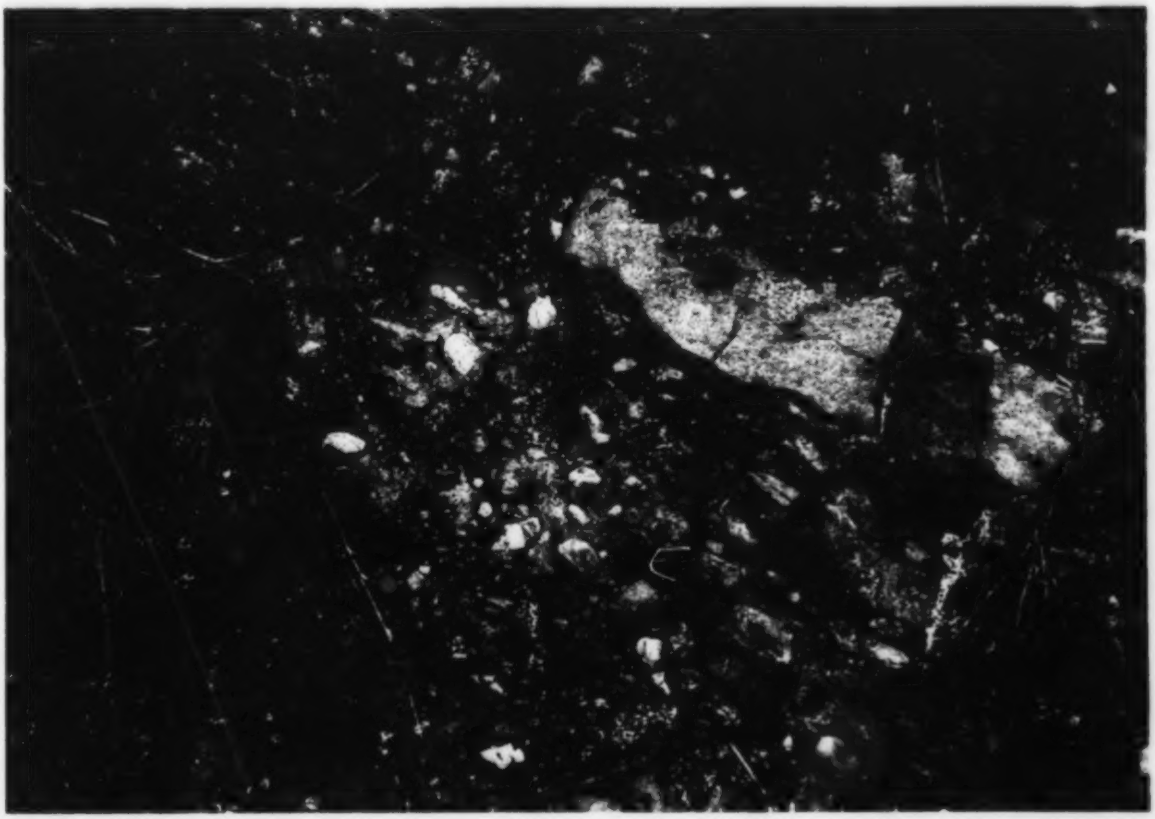


Photo 30. Polymict conglomerate (with clasts of quartzite, chert and carbonate) north of the Graveyard Lake valley and tentatively assigned to unit Ccgm.

the Road River Group, were also noted. These occurrences may represent outliers of younger units, or they may be lithological variations of Middle Cambrian sequences. The latter explanation is favoured considering the complex facies variations seen within rocks of Cambrian age in the southeastern Kechika Trough (Taylor *et al.*, 1979; Fritz, 1979).

West of the Kechika River, along the eastern slope of the ridge east of Aeroplane Lake, rocks tentatively assigned to the Middle Cambrian comprise interlayered dark grey to bluish grey argillite, cherty argillite, slate to phyllite and pale grey, laminated micaceous quartz sandstone. These rocks contain thick sections of massive to thickly bedded grey calcareous quartz sandstone with distinctive rip-ups of dark grey argillite. Other clasts consist of well rounded, vitreous quartz, chert, siltstone and limestone or calcite. Although this panel has similarities to Earn Group clastics, the calcareous quartz sandstone is atypical and its heterolithic character is not unlike clastics of Middle Cambrian age.

Age and Correlation of units Ccg *and* Ccgm

No fossils were recovered from rocks of the conglomerate and maroon facies. Its age is inferred from its relative stratigraphic position and correlation with similar units of known age elsewhere within the Kechika Trough. It occurs stratigraphically above archaeocyathid-bearing limestone of unit Cl and below carbonate of Cc, which is believed to be Middle to Late Cambrian in age. One of its distinguishing features is the conglomeratic facies, which, from its coarseness and abundance of incompetent clasts such as limestone and siltstone, suggests erosion of local lithologies due to rapid uplift. Similar rocks (interpreted as a fanglomerate), with associated red beds, occur in the same stratigraphic position in the Tuchodi and Ware map areas. It is one of numerous Cambrian facies found in the southern Kechika Trough and adjacent shelf (Taylor *et al.*, 1979; Taylor and Stott, 1973; Fritz, 1979; 1991) and is referred to as the 'Roosevelt facies' due to its excellent exposure near Mount Roosevelt (Fritz, 1991). Sections of similar conglomerate and red or maroon beds are described near Mt. Sylvia in the Ware (94F) map area (Fritz, 1979). The conglomerate and associated red beds are more than 1525 metres thick at Mount Roosevelt. In both areas, the base of the conglomeratic facies is believed to occur just above the Lower-Middle Cambrian boundary (Fritz, *ibid.*).

CARBONATE (Cc)

Most of the spectacular peaks in the Gataga River area are underlain by steeply dipping panels of thick-bedded limestone and dolostone (Photos 2 and 31). It is the disappearance of these carbonates at Terminus Mountain that marks the northern end of the Rocky Mountains. Excellent carbonate exposures are found along the ridge northeast of the Gataga River in the southeast part of the study area. This carbonate panel can be traced to the northwest where it thins and finally disappears into shales and siltstones southeast of Netson Lake. Split Top Mountain represents the next westerly belt of this carbonate package. Several ridges of carbonate that trend northwest from this area delineate splays off the main thrust at the base of Split Top Mountain (Photo 32). These carbonate sections also thin northwestward and the last carbonate associated with this fault zone shales out a few kilometres north of Brownie Mountain. These rocks are well exposed north and south along the ridge containing Brownie Mountain and there are spectacular exposures to the east along the hangingwall of the Gataga Mountain thrust fault. This same panel can be traced northward, along the west side of the Gataga Mountain anticline and onto the west slopes of Terminus Mountain. Unit Cc is also found on the overturned east limb of this anticline. This carbonate is also present within impressive klippe sitting above Road River siltstones several kilometres southeast of Terminus Mountain.

Thicknesses and lithologic characteristics of these rocks change dramatically across the map sheet. Approximately 1500 metres of carbonate are inferred from structural sections through the rugged ridge west of Brownie Mountain, whereas only 700 metres of carbonate are exposed on the ridge along the southeastern boundary of the study area. The northward thinning and disappearance of these carbonates is illustrated by this section which thins progressively from an initial 700 metres.

The carbonates are generally massive and fairly 'clean', unlike the Lower Cambrian carbonates described earlier. Although thin beds of sandy limestone to limy sandstone or quartzite occur locally, they are relatively uncommon. The only exception to this are mappable siliciclastic units found within this carbonate succession in the far southeastern part of the map area (unit Ccs). The Lower Cambrian carbonates also tend to be darker weathering than the grey to light grey carbonates of unit Cc. The dominant lithology is massive to thickly bedded, grey to tan weathering, grey to white micritic to finely recrystallized limestone. Thin, discontinuous beds of more resistant, lighter coloured dolostone and dolomitic limestone are locally present. Intraformational carbonate breccia and conglomerate are less common but were mapped within the easternmost limestone body (Photo 33). Fenestral dolostone was also seen toward the base of this limestone panel. Large sections of the sequence have been variably dolomitized, forming massive buff to orange-weathering sections in the Split Top Mountain area, at Brownie Mountain and along the ridge to the west. Limestone or dolostone locally contain up to 30 per cent well rounded quartz grains and local interlayers of thin to thick beds or sections (up to 5 m thick) of white to tan-weathering quartzite give the succession a distinctive ribbed appearance.

Intra-Carbonate Siliciclastics (Ccs)

Siliciclastics and lesser carbonates form lenticular sequences between 30 and 150 metres thick within carbonate sections of unit Cc along the footwall of Netson Creek thrust fault south of Bluff Creek. They consist of thin to moderately bedded, grey and brown to tan-weathering, grey siltstone, slate and quartz sandstone, interlayered with lesser grey to buff-weathering sandy limestone, sandy dolomite, dolomite and dark grey argillaceous limestone. Sandstone is wavy to planar bedded whereas siltstone and slate sections have colour banding or striping and frequently worm burrows on bedding planes.

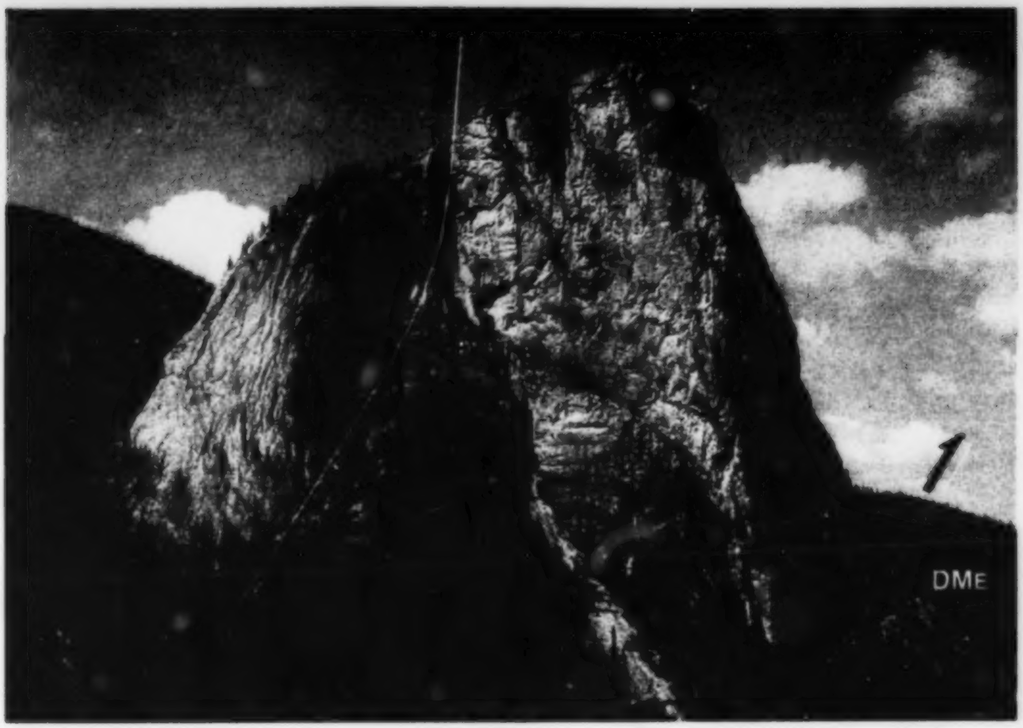


Photo 31. Looking northwest at the most northerly exposure of carbonate of unit Cc found along the Split Top Mountain thrust fault. This photograph clearly shows the cliff-forming nature of this lithology. This panel shows internal folding along the edge of the thrust fault and there are indications that it is also cut by another thrust to the east.

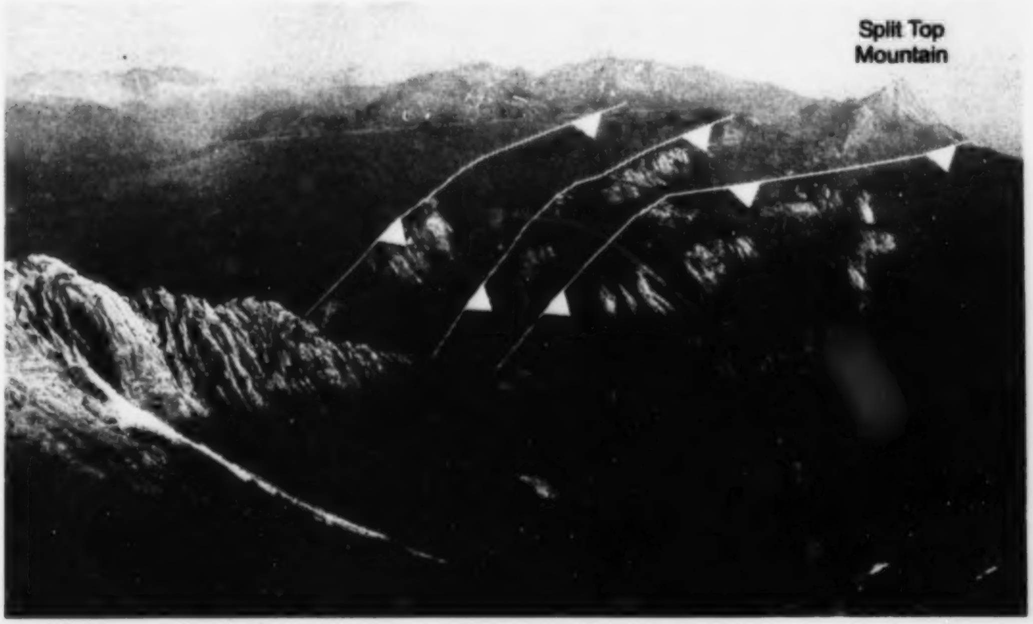


Photo 32. View to the southeast from the eastern slopes of Brownie Mountain. Split Top Mountain is the isolated peak at the right of the skyline. This picture shows the well exposed nature of unit Cc which delineates several thrust panels in this locality.

Photo 33. Carbonate breccia within unit Cc, approximately 6 kilometres due east of Split Top Mountain.

Age and Correlation of Units Cc *and* Ccs

No fossils were recovered from carbonates or siliciclastics of this package within the map area. The age of these rocks is based on correlations with similar lithologies farther to the south. Fritz (1980a) describes two sections of Cambrian rocks 50 and 80 kilometres south of the study area, near the headwaters of the Gataga River. These sections are dominated by siliciclastics in the lower parts and succeeded by clean carbonates, a sequence not unlike Csc and Cc in the Terminus Mountain area. Late Early Cambrian fossils were recovered from the base of the carbonate at one locality. Late Cambrian fossils were collect from the upper parts of both sections, although the top of one section is Dresbachian in age, whereas the other extends upwards into the Trempealeauan. In our study area, polymictic conglomerate and maroon beds of probable early Middle Cambrian age are exposed below carbonate of unit Cc, suggesting the base of the unit, like the top, may be diachronous.

Unit Cc essentially corresponds to Gabrielse's (1962a) unit 5. These carbonates can be traced into the Driftpile Creek and Akie River areas where McClay *et al.* (1988) and MacIntyre (1992, 1998) describe thick carbonate sequences at the top of the Cambrian succession. Gabrielse *et al.* (1977) also describe thick, isolated carbonate buildups of Middle and Late Cambrian age in the southern Kechika Trough. As Fritz (1991) has pointed out, these carbonates are essentially the northward extension, albeit somewhat more condensed, of the well known Middle and Late Cambrian carbonate succession that comprise the spectacular peaks of the Eastern and Main ranges of the central Rocky Mountains.

North of 60°, thick sections of Middle and Late Cambrian carbonates reappear along the Mackenzie platform and comprise dolostone of the Avalanche Formation and dolostone, limestone and siliciclastics of the Broken Skull Formation (Gabrielse *et al.*, 1973; Gordey and Anderson, 1993).

ENVIRONMENT OF DEPOSITION AND TECTONIC SIGNIFICANCE OF CAMBRIAN STRATA

Overall, Cambrian lithologies in the eastern and northern parts of the map area are more pelitic, finer grained, and much less calcareous than those exposed in the highlands along the southwestern or southeastern margin. Restoration of shortening represented by thrusting and folding would probably result in a considerable separation between the two depositional environments. A preliminary interpretation of these observations is that Early Cambrian facies in the southwestern part of the map area represent a relatively shallow-marine to intertidal setting, with sedimentation fluctuating between coarse siliciclastic and carbonate deposition, resulting in interfingering lithological units. In contrast, the contemporaneous sedimentation represented by the Cambrian rocks farther east probably took place in deeper water and under more uniform conditions. This latter environment received periodic influxes of coarse carbonate debris shed from buildups to the west.

This sedimentation was interrupted at the beginning of the Middle Cambrian by uplift along steep faults, probably related to extensional tectonism and possibly linked to alkalic volcanism represented by unit **CPv**. This tectonism led to the deposition of the coarse fanglomerates and maroon beds of units **Ccg** and **Ccgm**. More stable conditions returned to the area with sedimentation dominated by shallow-water carbonate deposition which may have been localized along the tops of rotated blocks produced during the early Middle Cambrian tectonism. Water was relatively deep between carbonate build-ups, resulting in starved shale basin deposition.

Similar regional facies variations in Lower, Middle and Upper Cambrian successions have been documented elsewhere in the Selwyn and Kechika basins (Gabrielse, 1981; Fritz, 1979, 1991; Taylor *et al.* 1979; Gordey and Anderson, 1993). Siliciclastic to carbonate facies variations within the platformal sections of the Early Cambrian Sekwi Formation are well documented in the Selwyn Basin as is its basinward change into the Gull Lake Formation (Fritz, 1991; Gordey and Anderson, 1993). The Lower Cambrian facies distribution represented by units **Cs** and **Csc** suggests that the western edge of the Kechika Trough may have been located within the map area during this time.

In the southern Kechika Trough, Gabrielse (1981) documented the existence of six facies within rocks of Middle (and Late?) Cambrian age. These included thick carbonates in a platform or northwest-trending linear reef configuration surrounded by shale, siltstone, sandstone and platy limestone of clastic or starved basin settings. Sections of olistostromes and debris flows were also found between areas of large carbonate build ups.

In the Ware map area, along the eastern margin of the Kechika Trough, up to four facies sequences were recognized in the Middle Cambrian (Taylor *et al.*, 1979; Fritz; 1979, 1991). A complete description is beyond the scope of this paper, but these facies describe the presence of a north-trending trough (Fritz, 1979) and are very similar to Middle and Upper Cambrian lithologies observed in the course of this study. The trough received detritus, some of which has a distinct red colour, from uplifted areas around it. In some localities the redbeds consist of coarse red-weathering conglomerate which can be related to large normal faults. These coarse clastics are succeeded locally by thick sections of limestone or dolomite which can be shown to shale-out westward. Carbonate deposition is believed to have been restricted to the shallower parts of uplifted blocks towards the west (Fritz, 1979).

Our observations are entirely consistent with the extensional tectonism and sedimentation described in the southern Kechika Trough. Furthermore, if alkalic volcanics of unit **CPv** are Middle Cambrian as theorized, then they would lend further support to this time being a period of major extensional tectonism within the northern part of the ancestral North American miogeocline.

KECHIKA GROUP (COK,COKS)

The name Kechika Group was first proposed by Gabrielse (1963) in the Cassiar Mountains and was later used by Jackson *et al.* (1965) to describe Upper Cambrian to Upper Ordovician strata in the Trutch and Ware map areas and in the Tuchodi Lakes map area by Taylor and Stott (1973). Middle and Upper Ordovician strata of the Kechika Group that lie east of the Northern Rocky Mountain Trench were later reassigned to the overlying Road River Group. The present application of the term 'Kechika Group' to argillaceous carbonates and shales of Late Cambrian to Early Ordovician age in Kechika Trough was first used by Gabrielse *et al.* (1977) in the Ware map area. Cecile and Norford (1977), working in the east half of the Ware map area, suggested that this unit be termed a formation. Considering the facies variation within this package, group status is probably more appropriate and will accommodate any future subdivisions.

Rocks of the Kechika Group, like the underlying Middle to Upper Cambrian carbonates of unit **Cc**, exhibit a marked facies change and thinning from southeast to northwest in the southern part of the study area. This transition is quite abrupt and roughly corresponds to the disappearance of the underlying thick sequences of Lower to Upper(?) Cambrian limestone and quartzite. Sections of Kechika Group are calcareous and approximately 500 metres thick along the southeastern margin of the study area and decrease northwestward, along strike, to less than 50 metres of dark slate. A maximum of only 50 metres of Kechika rocks is also found along the southern part of the Netson Creek thrust panel where Middle and Upper Cambrian carbonates are missing. These rocks thin further to the northwest and were recognized only locally in the lowlands south of Horneline Creek. Furthermore, it is sometimes difficult to determine if black slates between siltstone of unit **SDRR** and siliciclastics of unit **Cs** are part of the Kechika Group or the lower Road River Group. This is particularly evident in the well exposed highlands east of Split Top Mountain, where Silurian rocks of the Road River Group are found less than 50 metres above Cambrian clastics and only black slates of possible Ordovician Road River affinity separate the two. The apparent absence of these thin, recessive rocks in the subdued regions to the north may be a function of the overall poor exposure in this area. North of Horneline Creek, the Kechika Group again thickens and becomes more calcareous. Structural sections suggest thicknesses upwards of 1000 metres. In the north, the Kechika Group contains thicker horizons of limestone and abundant calcareous siltstone, neither of which is well represented in the southern part of the map area.

Some of the thickest and best exposed sections of this unit are found in the south, between Terminus and Split Top mountains. Relatively good exposures crop out along northeast-trending ridges emanating from the high ground between Gataga and Terminus mountains. Outcrops are also found along the banks of many of the creeks throughout the map area. Only small, isolated outcrops are found along ridges or hilltops north of Horneline Creek and good exposures are only found along creek valleys.

South of Terminus Mountain, the Kechika Group is characterized by interlayered grey to dark grey, soft slate, calcareous slate or rare silty slate and grey, buff or orange-weathering, very finely crystalline limestone or dolostone (Photos 34, 35). The carbonate layers are generally discontinuous to lenticular and typically 0.1 to 2 centimetres thick, although locally they reach several metres in thickness. They comprise up to 50 per cent of the section locally but average 20 per cent. This facies is exposed above thrust panels of Cambrian limestone. The northernmost outcrop area of this lithology is on the lower slopes of the Rocky Mountain Trench, north of Terminus Mountain, where it is characterized by banded to mottled, orange to brown-weathering, grey to dark grey calcareous slate to silty slate. This facies of the Kechika Group covers a wide area east of Gataga Mountain, reflecting the northward plunge of the Brownie Mountain anticline. These rocks also cover a large area along the lower reaches of Matulka Creek. The thickness of Kechika slates and carbonates is difficult to determine due to strong deformation. Structural sections suggest upwards of 500 metres of Kechika rocks immediately south of Matulka Creek.

The base of the formation, where seen, is typically composed of 25 to 50 metres of black to dark grey slate with lenses or discontinuous layers of grey to orange-weathering limestone or dolomite. This is particularly well exposed along the top of unit Cc in the hangingwall of the Netson Creek thrust fault and west of Brownie Mountain. This sequence is very similar to thin Kechika sections seen resting directly on top of siliciclastics of unit Cs.

Immediately east and southwest of Brownie Mountain and south of the Gataga River, the Kechika Group is lighter coloured and typified by grey to silvery slate, calcareous slate and silty slate with lesser thin beds or lenses of grey limestone (Photo 35). In this area, Kechika slate has characteristic light and dark grey laminations resulting from increased silt and/or carbonate content within lighter coloured horizons. Thin interlayers of grey limestone, from 0.5 to 10 centimetres thick, are abundant in the lower 50 metres.

The calcareous nature of this facies of the Kechika Group is lost up-section and the upper half or one-third is characterized by grey to dark grey or black, blocky to shiny

Photo 34 Lighter coloured thick, calcareous Kechika facies south of Gataga River, and immediately east of Brownie Mountain. Tight folding, with a strong axial planar cleavage, can be seen in this photograph which reflects the very incompetent nature of these rocks.

Photo 35. Close-up of interlayered light and dark grey argillite to calcareous argillite or silty argillite in the Kechika Group east of Gataga Mountain. The Kechika Group becomes dominated by the lighter coloured lithologies south of the Gataga River.

fissile slate, with characteristic faint discontinuous, paler grey laminae. Thin, discontinuous or lensoidal beds of finely crystalline limestone are occasionally present in the lower part of this sequence. Sections of dark grey banded slate, up to 100 metres thick, occur in typical calcareous sections of lower Kechika slates west of Gataga Mountain and are probably infolded sequences of upper Kechika Group. These upper slates are difficult to differentiate from Ordovician Road River slates and have been grouped with them over most of the map area (*see* below).

East of the headwaters of Matulka Creek, the pale coloured and soft calcareous facies of the Kechika Group is recognized in only a few localities. Interlayered grey to buff-weathering, thinly bedded limestone and slate or calcareous slate outcrop along the top of the first ridge northwest of Netson Lake. These lithologies are exposed near the base of a sequence which passes upward through dark grey to black slate into black graptolitic slates of the Road River Group. This section appears to be several hundred metres thick.

Elsewhere in the central and southern parts of the map area, calcareous Kechika rocks are uncommon and a thin section of dark grey or black shale or slate and lesser carbonate, up to 50 metres thick, occupies the same stratigraphic position. Assignment of these rocks to the Kechika Group is based on their overall similarity to basal parts of thick Kechika sections seen sitting directly above Cambrian carbonate of unit **Cc**. These rocks are very similar to sections south of Horneline Creek; this thin, noncalcareous facies occurs above fine basinal siliciclastics of Cambrian age. This is in sharp contrast to the thicker, calcareous Kechika Group which is found above the thick Middle to Late Cambrian reefal or shelf carbonates. The shale facies of the Kechika Group is well exposed along the top of the thrust panel carried by the Netson Creek thrust fault. Thrust panels on either side contain thicker sections of calcareous Kechika Group that lie stratigraphically above carbonate of unit **Cc**.

The lower half of the thin shale facies consists of dark grey to black slate with layers or lenses of orange to grey-weathering dolomitic limestone to limestone that comprise 30 to 50 per cent of the section and which decrease in abundance toward the top. Slate in the lower part is locally lighter coloured above thin limestone in the upper parts of unit **Cs**. Green slate up to 5 metres thick, which has distinctive crystals of barite up to 1 centimetre long, is found at the base of this facies, in the hangingwall of the Netson Creek thrust fault east of Split Top Mountain. Barite crystals were also observed in basal calcareous horizons of the Kechika Group in the northernmost part of this thrust panel.

The upper half of this facies consists of dark grey to black slate with rare limestone or dolomitic limestone lenses. Locally, upwards of 20 metres of orange-weathering, cleaved, bioturbated dolomitic slate to silty slate is present in this section.

The Kechika Group abruptly thickens north of Horneline Creek, where it consists of thinly to thickly interbedded calcareous slate and limestone or silty limestone. On lower Horneline Creek, Kechika rocks are primarily thinly interlayered grey to dark grey slate, calcareous slate and limestone. Limestone is locally discontinuous and displays thin planar or rare crosslaminations. In some areas it forms a large proportion of the section, with beds up to 1 metre thick. These rocks can be traced northward toward Chee Mountain, where the slates have a characteristic silvery lustre. Southeast of Graveyard Lake, the Kechika Group comprises thinly interlayered, shiny pale to dark grey slate, calcareous slate and pale to medium grey, fine to very fine grained limestone. Limestone is often well laminated and silty, and bedding surfaces locally have mud cracks and worm burrows. Interbedding of slate and limestone varies from thin rhythmic tabular limestone beds to discontinuous lenses, or on a larger scale, consists of alternating thicker sections of noncalcareous slate and platy grey limestone.

Northwest of Graveyard Lake, the Kechika Group occupies a large area which extends northward to the Kechika River. The Kechika is unusual in this area in that it is uncharacteristically more siliceous and more dolomitic. The rocks consist of thinly interlayered grey to orange-weathering, pale to medium grey silty slate, calcareous slate and calcareous siltstone to fine sandstone, all of which are locally finely laminated to crosslaminated (Photo 36). Mica flakes are visible on some bedding surfaces. These rocks locally grade into silty limestone or dolostone. North of Gemini Lakes, grey to beige-weathering, dark grey, platy micritic limestone to argillaceous limestone forms sections up to 10 metres thick. This limestone is locally dolomitic, contains thin slate partings and displays a spaced cleavage in the more argillaceous parts. The Kechika Group in this area has similarities with equivalent strata to the east which is found closer to the platform edge.

The nature of the lower Kechika Group contact is equivocal. The Kechika Group appears to rest unconformably on Cambrian carbonates at several localities. Along the eastern foot of Brownie Mountain, the very base of the Kechika Group contains cobble-sized clasts(?) or lenses(?) of carbonate similar to limestone in underlying unit **Cc**. A similar situation is seen in the southeastern part of the map area, along the footwall of the Netson Creek thrust, where basal Kechika slates contain blocks of the underlying Cambrian carbonate. Northeastward along the same thrust panel, uppermost carbonate units of **Cc** appear to grade into overlying basal slates and calcareous slates of the Kechika Group over a distance of approximately 1 metre (Photo 37a). The lower 5 to 10 metres of the Kechika Group contains discontinuous layers or lenses of grey carbonate up to 50 centimetres thick which are very similar to underlying carbonate of **Cc**. Fritz (1980) describes similar, apparently conformable relationships between these two units south of the Kechika River.

This relationship is also ambiguous where the thick Middle and Upper Cambrian carbonates are lacking and Kechika slates rest directly on slates and siltstones of unit **Cs**. This contact is well exposed east of Split Top Mountain where the first orange-weathering limestone beds of the Kechika Group overlie approximately 25 metres of dark grey to black slate which gradationally overlies Cambrian siliciclastics (Photos 37b, 39). These dark slates are similar

Photo 36. Typical section of lighter coloured calcareous Kechika Group north of the Graveyard Lake valley. The unit contains considerably more siltstone and sections of limestone up to 5 or 10 metres thick. The argillaceous component still predominates and is reflected in its incompetent nature, shown here by tight, pervasive folding and associated penetrative cleavage.

in appearance to slates interlayered with the overlying orange and grey limestones of the Kechika Group. The relationship here appears conformable.

Similarly, upper slates of the Kechika Group appear to grade into basal slates of the overlying Road River Group. The similarity of these two packages makes separating them difficult. This is particularly evident in areas where only the thin, slaty facies of the Kechika Group is present.

Age and Correlation

Micro and macrofossil collections made over the course of mapping suggest a Late Cambrian to Early Ordovician age for the Kechika Group (*see* Table 3a and b). No diagnostic fossils were recovered from the base and the top of this package. Graptolites within lower Road River Group, several metres above the upper contact of the Kechika Group, indicate a late Early Ordovician (early to middle Arenigian) age. Conodonts from the base of the Kechika Group, only a few metres above limestone of unit Cc, span Late Cambrian to Tremadocian (earliest Early Ordovician) time (locality F_{25}; *see* Table 3a). This is in agreement with a regional Late Cambrian lower age range for the Kechika Group. Although several of the fossil collections extend into the early Middle Ordovician (Llandoverian), most suggest a late Early Ordovician age for the upper age range. This is again consistent with the highest beds of the group being Arenigian (B.S. Norford, personal communication, 1994).

Immediately south of the Gataga River, Fritz (1980a) collected fossils from the very base of the Kechika Group, and at the top of underlying carbonate equivalent to unit Cc. The data suggest a Late Cambrian age and also indicate the contact between the two units is diachronous. In one section, fossils indicate the contact is Dresbachian (early Late Cambrian), whereas collections from a nearby section suggest the top of the underlying carbonate is Trempealeauan (late Late Cambrian) in age.

The Kechika Group, and its equivalents, represent a widely distributed shelf and basin carbonate facies found along the entire length of the Canadian Cordillera. The name is used within the Kechika Trough, into the MacDonald and Kakwa platforms, and across the Northern Rocky Mountain Trench in the Cassiar platform (Gabrielse, 1963, 1998; Gabrielse *et al.*, 1977; Cecile and Norford, 1979; Taylor *et al.*, 1979; Taylor and Stott, 1973; Thompson, 1989). In the Mesilinka River map area, Gabrielse (1975) referred to this sequence as the Mount April Formation; one of the original two formations of the Kechika Group first proposed by Jackson *et al.* (1965) in the northern Rocky Mountains. Gabrielse's (1966) unit 4 within the Watson Lake map area is in part, or entirely, equivalent to rocks of the Kechika Group. To the east, Gabrielse and Blussson's (1969) unit 8 in the Coal River map area has the same age and lithologic character as rocks of the Kechika Group. These rocks can be traced northward into the Flat River and Glacier Lake map areas where they are termed the Rabbitkettle Formation (Gabrielse *et al.*, 1973). This name has been applied to rocks of the same age and character over much of the Selwyn Basin (*see* Gordey and Anderson, 1993). Platform equivalents of these units are not preserved in the MacDonald and Kakwa platforms. Shallow-water correlatives along the Mackenzie Platform, to the north, include the parts of the Broken Skull and Franklin Mountain formations (Gabrielse *et al.*, 1973; Gordey and Anderson, 1993).

The regional significance of thinning and facies variation within the Kechika Group of the study area, particularly in the south, is not fully understood. Generally, the Kechika Group is thicker, and contains abundant calcareous material where it sits above Middle to Upper Cambrian carbonate of unit Cc (Figure 16). Where Cambrian carbonate is lacking, rocks assigned to the Kechika Group are typically less than 50 metres thick, composed almost entirely of dark slate and indistinguishable from basal Road River slates. This latter scenario strongly suggests the presence of a sub-upper Road River unconformity.

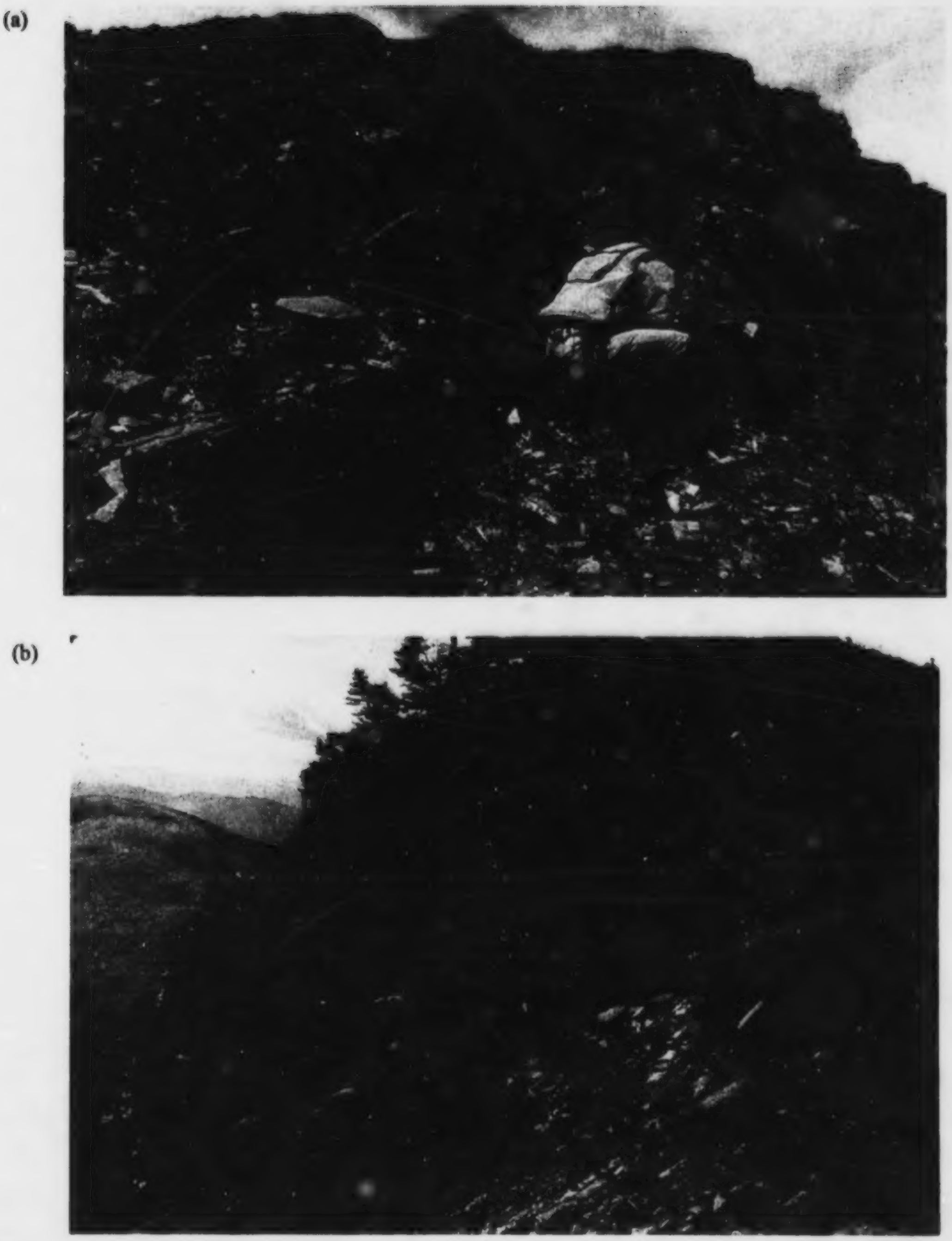


Photo 37. These two photographs display sections of dark grey to black argillite and calcareous argillite with distinctive interlayers or lenses of grey to orange-weathering (primarily along bedding surfaces) limestone to dolomite. Both sections are from 25 to 50 metres thick and are assigned to the basal Kechika Group. Section (a) occurs immediately above several hundred metres of carbonate of unit Ꞓc some 6 kilometres east of Split Top Mountain and is succeeded by more typical interlayered light to dark grey calcareous argillite, slate and minor siltstone of the Kechika Group. Section (b) occurs just north of Bluff Creek and along the top of the panel of Ꞓs sediments with no thick carbonate of Ꞓc between the two lithologies. Approximately 5 metres of grey limestone, with a few per cent floating sand grains, sits conformably below this lithology and the carbonate grades downwards into some 50 metres of black slate which sits conformably on typical siliciclastics of Ꞓs. Black graptolitic slates of Middle Ordovician age, and belonging to the lower Road River Group, sit only 50 metres stratigraphically above the base of the Kechika section shown in section (b).

TABLE 3A
FOSSIL IDENTIFICATIONS FOR THE SOUTHERN MAP AREA
MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 2

Map No.	Rock Unit	GSC Loc. No.	Field No.	Easting	Northing	Taxa	Classification	Age	Remarks
1	Ca		CRE95-27-16	623200	6516620	archaeocyathids	archaeocyathids[8]	Early Cambrian	
2	Ca	C-208317	CRE95-25-6-2	625185	6514135	archaeocyathids coralomorph and indeterminate fragments of large trilobites	*Acanthopyrgus* sp.[1] *Mackenziecyathus* sp.[1] *Tabulaconus* sp.[1]trilobite fragments[1]	Late Early Cambrian	*Tabulaconus* does occur with datable trilobites in the Mackenzie Mountains (Fritz, 1979), suggesting that the present collection is from the lower part (but not lowest) of the *Bonnia-Olenellus* Zone
3	Ca	C-208853	JN94-5-4	646150	6488000	archaeocyathids	archaeocyathids[2]	Early Cambrian	archaeocyathids in the Cordillera seem to be restricted to the interval *Nevadella* Zone to mid *Bonnia-Olenellus* Zone (Fritz, 1991)
4	Ca	C-208855	JN94-3-2	646750	6487200	archaeocyathids	archaeocyathids[2]	Early Cambrian	•
5	Ca	C-208867	FFE94-29-3	638225	6501250	archaeocyathids	archaeocyathids[2]	Early Cambrian	•
6	Ca	C-208868	FFE94-30-2	637600	6488385	archaeocyathids	archaeocyathids[2]	Early Cambrian	•
7	Ca	C-208869	FFE94-1-5-2	645220	6489410	archaeocyathids	archaeocyathids[2]	Early Cambrian	•
8	Ca	C-208870	FFE94-2-2-2	644310	6488900	archaeocyathids	archaeocyathids[2]	Early Cambrian	•
9	Cac	C-208905	JN95-8-3	612315	6510250	archaeocyathids	archaeocyathids[4]	Early Cambrian	•
10	Cac	C-208906	CRE95-22-4	610415	6513800	archaeocyathids	archaeocyathids[4]	Early Cambrian	•
11	Kechika Group	C-208851	JN94-GA-4	647700	6487350	graptolites	*Clonograptus* sp.[2]	mid-Early Ordovician to early Middle Ordovician	
12	Kechika Group	C-208852	JN94-1-3a	647700	6487350	graptolites	?*Clonograptus* sp.[2] *Tetragraptus* sp.[2]	Early Ordovician, probably Arenigian or late Tremadocian	
13	Kechika Group	C-208856	JN94-1-1	647650	6487200	graptolites	?*Caryocaris* sp.[2] ?*Clonograptus* sp.[2] *Tetragraptus* sp.[2]	Early Ordovician, probably Arenigian but possibly late Tremadocian	
14	Kechika Group	C-208857	JN94-1-2	647650	6487700	graptolites	?*Clonograptus* sp.[2] ?*Tetragraptus* sp.[2]	probably Early Ordovician	
15 ·	Kechika Group	C-208858	JN94-GA-6	647650	6487700	graptolites	?*Clonograptus* sp.[2]	Ordovician, probably Early or early Middle	
16	Kechika Group	C-208862	FFE94-4-2-2	645245	6490375	graptolites	graptolite fragments[2]	not diagnostic	
17	Kechika Group	C-208863	FFE94-4-4	645455	6490430	graptolites	graptolite fragments[2]	probably Ordovician	
18	Kechika Group	C-208864	FFE94-5-1	645595	6490455	graptolites	*Clonograptus* sp.2	Early Ordovician to early Middle Ordovician	
19	Kechika Group	C-208873	FFE94-4-2	642500	6490370	conodonts	oistodiform element (1)[5] *Drepanoistodus*? (2)5*Panderodus* sp. (2)[5] *Periodon*? sp. (5)[5]	Ordovician	
20	Kechika Group	C-208874	FFE94-5-2	645800	6490300	tubes[6]		Phanerozoic	
21	Kechika Group	C-208875	FFE94-6-2	646650	6488000	conodonts trilobites microcoprolites	*Phakelodus*? sp. (3)[5]	Late Cambrian?	Phosphatized microfauna
22	Kechika Group	C-208884	FFE94-21-3-1	640340	6496740	conondonts echinoderms inarticulate brachiopods	*Cordylodus*? sp(p). (15)[5]	Late Cambrian to Early Ordovician, Tremadocian	
23	Kechika Group	C-208886	FFE94-29-16	635205	6500000	sponge spicules[6] inarticulate brachiopods[6]		?Ordovician to Devonian	

TABLE 3A CONTINUED

22	Kechika Group	C-208884	FFE94-21-3-1	640340	6496740	conondonts echinoderms inarticulate brachiopods	*Cordylodus*? sp(p). (15)[6]	Late Cambrian to Early Ordovician, Tremadocian	
23	Kechika Group	C-208886	FFE94-29-16	635205	6500000	sponge spicules[6] inarticulate brachiopods[6]		?Ordovician to Devonian	
24	Road River Group	C-208903	JN95-3-4	632565	6501600	graptolites	?*Clonograptus* sp.[4] *Didymograptus* sp. (extensiform)[4] *Tetragraptus* sp.[4] *T.* ex gr. *T. quadribrachiatus* (Hall)[4] *Pendeograptus fruticosus* (Hall)[4]	Early Ordovician, Arenigian, *P. fruticosus* Zone or possibly lower part of overlying *D. bifidus* Zone	
25	Road River Group	C-208904	JN95-7-8	609100	6514900	graptolites	?*Caryocaris* sp.[4] ?dendroid graptolite[4] *Clonograptus* sp. *Didymograptus* sp. (extensiform) *Tetragraptus* ex gr. *T. quadribrachiatus* (Hall)	Early Ordovician, Arenigian, *T. akzharensis* Zone, *P. fruticosus* Zone, or possibly lower part of *D. bifidus* Zone	
26	Kechika or Road River groups	-	CRE95-5-5-2	620415	6503985	graptolites[9]		Not determined	
27	Kechika or Road River groups	-	FFE95-30-12	630900	6509675	graptolites[9]		Not determined	
28	Kechika or Road River groups	C-208318	CRE95-23-3	618570	6512275	graptolites	?*Clonograptus* sp.[3]	Early Ordovician, Arenigian or Tremadocian	
29	Road River Group	C-208328	FFE95-25-6-2	626850	6514545	conodonts sponge spicules	ramiform elements (2)[7] '*Spathognathodus*' sp. (2)[7]	Ordovician to Early Triassic	
30	Road River Group	C-208331	FFE95-36-1	617380	6527370	conodonts	ramiform elements (4)[7] *Panderodus* (1)[7]	Silurian to Middle Devonian	Pb, Sc, Sb, Sa elements
31	Road River Group	C-208332	FFE95-41-3	607700	6524525	conodonts sponge spicules mazuelloids	*Aspelundia fluegeli* (Walliser 1964) (2)[7] *Walliserodus*? sp. (1)[7]	Early Silurian, Llandoverian	Originally assigned to Earn Group
32	Road River Group	C-208333	FFE95-43-5	609800	6528150	conodonts	hindeodelliform element (1)[7] coniform element (1)[7]	probably Silurian	Could be a Drepanoistodus
33	Road River Group	C-208339	CRE95-26-3-2	624245	6515650	conodonts ?ichthyoliths	coniform element (1)[8]	Late Cambrian to Ordovician	
34	Road River Group	C-208341	CRE95-34-12	614360	6520950	tubes, ?protoconodonts[8]		Late Precambrian to Early Ordovician	
35	Road River Group	C-208342	CRE95-35-10-2	612830	6520160	sponge spicules[8]		Phanerozoic	
36	Road River Group	C-208344	CRE95-39-7	607230	6527160	sponge spicules[8] inarticulate brachiopods[8]		?Ordovician to Devonian	
37	Road River Group	C-208345	CRE95-44-3	610260	6527260	conodonts sponge spicules mazuelloids	*Distomodus*? sp. (1)[7]	probably Early Silurian	Originally assigned to Earn Group. Platform fragment resembles icriodiniform element. Accompanying mirofossils are the same as those in Ffe-41-3

TABLE 3A CONTINUED

38	Road River Group	C-208860	JN94-3-10	645200	6485975	graptolites	*?Protospongia* sp.[2] *Monograptus* sp.[2]	Early Silurian, probably Wenlockian, possibly late Landoverian	Collected from Silurian siltstone scree In northeastern British Columbia sponges have been documented from rocks of the Road River Group that are stratigraphically above beds with latest Llandovery graptolites (Davies, 1966; Rigby and Harris, 1979), thus the age of this collection is likely to be Wenlockian.
39	Road River Group	C-208861	JN94-7-8	645150	6485790	graptolites	*?Climacograptus* sp.[2] *Orthograptus* sp.[2]	late Middle to Late Ordovician	
40	Road River Group	C-208866	FFE94-20-8	638540	6495300	graptolites	*Dicellograptus* sp.[2] *Orthograptus calcaratus* cf. *acutus* Elles and Wood[2] *Reteograptus* cf. *R. geinitzianus* Hall[2]	Middle Ordovician, Caradoc *bicornis* Zone or *clingani* Zone	
41	Road River Group	C-208872	FFE94-3-16-3	642800	6488930	conodonts	ramiform elements (5)[6] *Aphelognathus*? sp. (1)[6] *Paridon*? sp. (4)[6]	Ordovician	
42	Road River Group	C-208876	FFE94-7-15-2	640650	6490450	conodonts	ramiform elements (16)[6] *Pandorinellina steinhornensis* (Ziegler 1956) (7)[6] *Polygnathus nothoperbonus* Mawson 1987 (1)[6]	Early Devonian, Emsian	
43	Road River Group	C-208879	FFE94-8-5	639770	6491205	conodonts	ramiform elements (7)[6] *Belodella* sp. (26)[6] *Polygnathus* sp(p). (6)[6] *Polygnathus inversus* Klapper and Johnson 1975 (2)[6]	Early Devonian, Emsian	
44	Road River Group	C-208885	FFE94-22-2	642175	6490470	conodonts sponge spicules	*Dapsilodus* sp. (1)[6]	Late Ordovician to Middle Silurian, Ashgillian-Wenlockian	
45	Road River Group	C-208888	FFE94-34-2-2	629360	6484215	conodonts crioconarids	ramiform elements (23)[6] *?Ptygnathus bultyncki* Weddige 1977 (20)[6] *Panderodus* sp. (2)[6] *Polygnathus angusticostatus* Wittekindt (1)[6] *Ptygnathus linguiformis* Hinde 1879 (35)[6]	Middle Devonian, early? Eifelian	
46	Road River Group	C-208891	JN94-7-10	643925	6487100	conodonts	ramiform element (1)[5]	Ordovician to Devonian	
47	Road River Group	C-208892	JN94-3-10	645200	6485970	conodonts	ramiform elements (35)[5] *Latericriodus* sp. (2)[5] *Polygnathus nothoperbonus* Mawson 1987 (23)[5]	Early Devonian, Emsian	Graptolites were also recovered in scree at the same locality

TABLE 3A CONTINUED

48	Earn Group		JN95-8-6	622485	6512600	radiolaria[9]		Not determined	
49	Earn Group	C-208322	FFE95-13-1-2a	624950	6507125	conodonts	nothognathelliform element (1)[7] *Pelekysgnatus* sp. (1)[7]	probably Late Devonian	
50	Earn Group	C-208334	FFE95-47-8-2	609290	6519200	conodonts	hindeodelliform element[7]	Silurian to Triassic	
51	Earn Group	C-208338	CRE95-24-7	623110	6514000	conodonts radiolarians	*Parachirognathus* (1)[7] *Polygnathus* aff. *pseudofoliatus* Wittekindt 1966 (1)[7]	Middle to Late Devonian	Light concentrations should be searched for radiolarians
52	Earn Group	C-208877	FFE94-7-16	640710	6490460	ichthyoliths[8]		Phanerozoic	

[1] Fritz, W.H. (1995): Paleontological Report C6-1995-WHF, *Geological Survey of Canada*, Ottawa Paleontological Section.
[2] Norford, B.S. (1994): Paleontological Report C-S 10-BSN-1994, *Geological Survey of Canada*, Calagary Paleontological Subdivision
[3] Norford, B.S. (1995): Paleontological Report C-O 6-BSN-1995, *Geological Survey of Canada*, Calagary Paleontological Subdivision
[4] Norford, B.S. (1995): Paleontological Report C-O 5-BSN-1995, *Geological Survey of Canada*, Calagary Paleontological Subdivision
[5] Orchard, M.J. (1995): Paleontological Report MJO-1995-43, *Geological Survey of Canada*, Vancouver Paleontological Subdivision
[6] Orchard, M.J. (1995): Paleontological Report MJO-1995-40, *Geological Survey of Canada*, Vancouver Paleontological Subdivision
[7] Orchard, M.J. (1996): Paleontological Report MJO-1996-13, *Geological Survey of Canada*, Vancouver Paleontological Subdivision
[8] Orchard, M.J. (1996): Paleontological Report MJO-1996-15, *Geological Survey of Canada*, Vancouver Paleontological Subdivision
[9] Field Identification99

TABLE 3B
FOSSIL IDENTIFICATIONS FOR THE NORTHERN MAP AREA
MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 3

Map No.	Rock Unit	GSC Loc. No.	Field No.	Easting	Northing	Taxa	Classification	Age	Remarks
1	Kechika Group	C-207906	FFE96-14-3	588995	6586147	conodonts	coniform elements (26)[1]	Early Ordovician, ?Arenigian	A diverse collection of small elements
2	Kechika Group	C-208347	CRE96-5-9	605156	6556269	conodonts	coniform elements (27)[1]	Early Ordovician, ?Arenigian	Collection includes drepanodiform, oistodiform, and scolopodiform elements
3	Kechika Group	C-207902	CRE96-18-5	576248	6609287	conodonts	coniform elements (6)[1] oistodiform element (1)[1]	Early? Ordovician	
4	Road River Group	C-207903	CRE96-20-9	604142	6530491	conodonts	"*Oulodus*" sp. (1)[1] *Dapsilodus*? sp. (1)[1] *Drepanoistodus*? sp. (1)[1] *Ozarkodina*? sp. (1)[1] *Walliserodus* sp. (3)[1]	Early Silurian, Llandoverian	
5	Road River or Earn group	C-207905	FFE96-12-9	576417	6588609	conodonts	ramiform elements (23)[1] *Belodella* sp. (5)[1] *Neopanderodus*? sp. (1)[1] *Polygnathus* spp. (8)[1] *Tortodus*? sp. (1)[1]	Middle-?Late Devonian, Eifelian-?Frasnian	
6	Road River Group			573930	6602865	graptolites	*Climacograptus* sp.[2] *Dicellograptus* sp.[2] *Orthograptus* sp.[2]	Upper Ordovician, Caradocian	

[1] Orchard, M.J. (1997): Paleontological Report MJO-1997-21, *Geological Survey of Canada*, Vancouver Paleontological Subdivision.
[2] Miller and Harrison (1981)

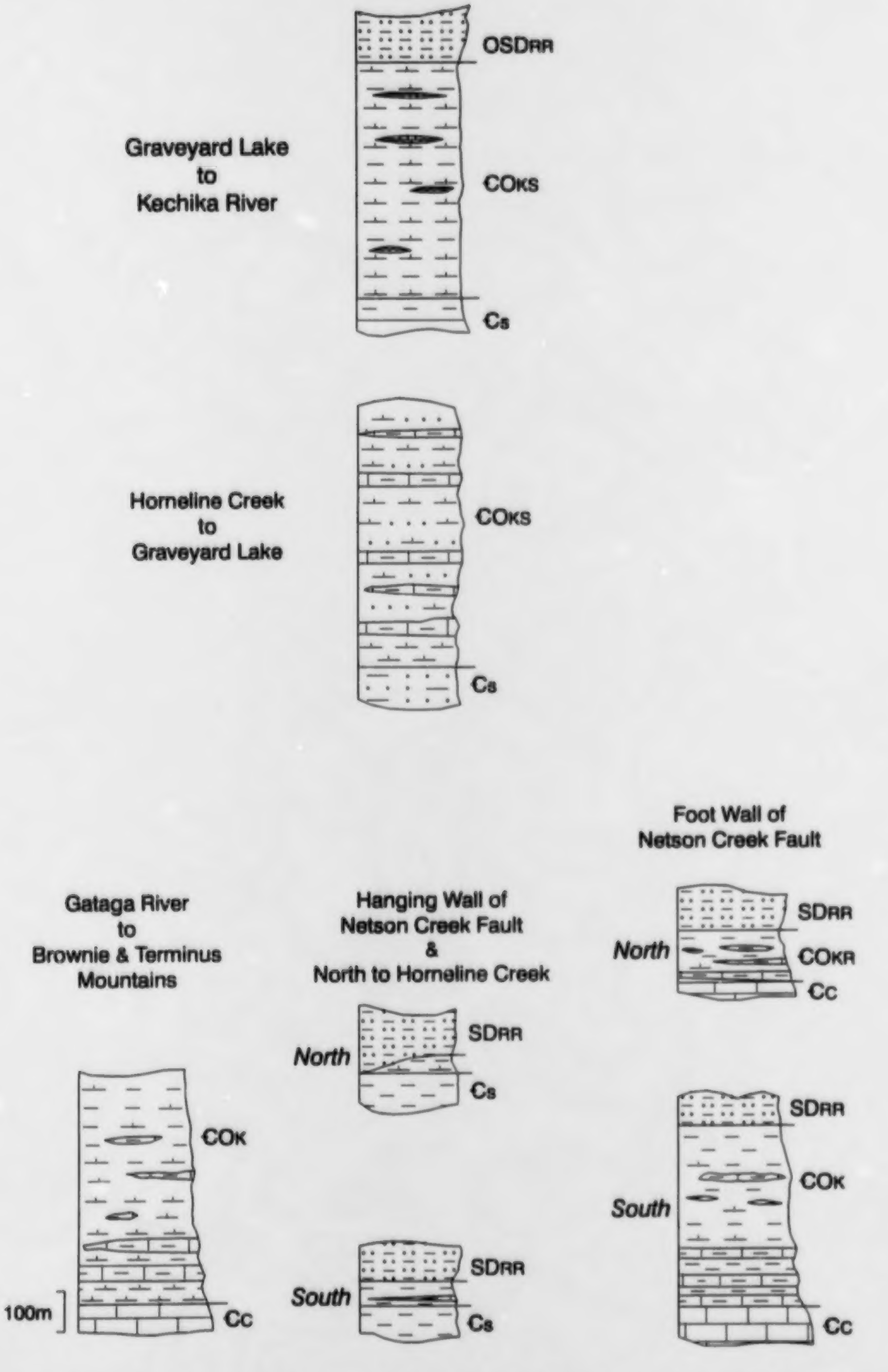

OSDRR
Graveyard Lake to Kechika River
COKS
Cs
Horneline Creek to Graveyard Lake
COKS
Cs
Foot Wall of Netson Creek Fault
Gataga River to Brownie & Terminus Mountains
Hanging Wall of Netson Creek Fault & North to Horneline Creek
North
SDRR
COKR
Cc
North
SDRR
Cs
COK
100m
Cc
South
SDRR
Cs
SDRR
COK
South
Cc

Figure 16. Schematic representation of thickness and lithologic variation of the Kechika Group within the map area.

This situation changes at the latitude of Horneline Creek, where the Kechika Group again begins to thicken and contain abundant calcareous material without the presence of underlying Cambrian carbonate of unit **Cc**. This siliceous, planar to crosslaminated limestone and dolostone is not typical of the of the Kechika Group in the project area, although regional correlatives with similar features occur in the Selwyn Basin (Gordey and Anderson, 1993; Cecile, 1982). The transition to this atypical Kechika lithology occurs rather abruptly across the Graveyard Lake valley, which may follow a long-lived basinal structure later utilized during contractional or strike-slip deformation.

The intermittent identification of the Kechika and lower Road River groups between rocks of the Upper Road River and siliciclastics of unit **Cs** north and east of Terminus Mountain is not fully understood. Their omittance may be depositional in nature (*i.e.* lack of sediment input) or the result of a sub-Upper Silurian Road River Group unconformity. A similar unconformity is postulated by Gabrielse (1981) to explain the apparent lack of lower Road River strata in the Ware area. Sub-Upper Silurian erosion or non-deposition has been inferred in the northern Kechika Trough by Cecile and Norford (1991). Although evidence for the presence of an unconformity is compelling, periodic recognition of thin Kechika and basal Road River may simply be a function of poor exposure, the recessive nature and thinness of these units. Furthermore, Middle Ordovician slates of the lower Road River Group are found above a condensed, slaty facies of the Kechika Group north of Bluff Creek, which strongly suggests that this thinning is not entirely due to later erosion or that, if an unconformity is present, it occurs below the lower Road River Group.

If the thinning of the Kechika Group is entirely depositional, it implies that certain parts of the basin received more sediment than others during Kechika time. The Kechika Group is very calcareous where its stratigraphic thickness is much greater than 50 metres. The lack of this calcareous material would result in a relatively condensed sequence of shale or argillite. This further suggests a relatively shallow-water environment where the Kechika Group is thickest, allowing for the production and deposition of more calcareous material. The basin must have been much deeper, and its sediment load much lighter, where the Kechika Group is considerably thinner and composed almost entirely of dark shale. These conditions mimic, to some degree, those in underlying Middle and Upper Cambrian sediments. Thick carbonate of unit **Cc** is believed to be reefal in character, which by its nature indicates shallow water. Between, and north of this carbonate, deeper water siliciclastics of unit **Cs** predominate. It seems that during Kechika time, sedimentation occurred along depositional elements formed in the Middle to Late Cambrian, although in somewhat deeper water conditions due to regional subsidence. This is, in part, substantiated by the conformable contact between Cambrian carbonate and overlying Kechika sediments seen at several localities in the map area and south of the Gataga River (Fritz, 1980).

In summary, it is not clear if the thinning and increased shaliness of the Kechika Group, together with the 'shaling-out' of underlying Cambrian carbonates are related, but their coincidence suggests that this part of the basin was subject to tectonic instability from Cambrian to Devonian times, resulting in marked facies changes and thinning or erosion of stratigraphy.

KECHIKA - LOWER ROAD RIVER GROUPS (COkr)

Over much of the map area, slates of the upper Kechika Group are sometimes difficult to distinguish from overlying slates of the lower Road River Group and, for mapping purposes, Kechika and lower Road River rocks have been combined into a unit designated **COkr**. In the central and eastern parts of the study area, south of Horneline Creek, dolomitic siltstones of the upper Road River Group are locally separated from Cambrian siliciclastics by a relatively thin section of blocky to fissile, dark grey to black slate to siliceous slate occupying the same stratigraphic position as the Kechika and lower Road River groups. Structural sections suggest combined thicknesses of, at the most, 100 metres. In many parts of the map area, proximity of Road River siltstones to Cambrian siliciclastics leaves little room for intervening slates of either the lower Road River or the Kechika groups.

Although these rocks share similarities with parts of both the Kechika and lower Road River groups, this thin section of dark coloured slates has more affinities with the lower Road River Group. It is best developed in thrust panels west of the Netson Creek thrust fault and east of Terminus Mountain, where it is composed of grey to brown-weathering, grey to dark grey or black shiny slates which are locally soft and fissile. Faint, paler grey colour banding or laminations are common and locally grade into more silty horizons with the characteristic mottling of the overlying Road River siltstones. Some outcrops contain sections of sooty black, slaty siltstone. Parts of this unit are characterized by dark grey to black siliceous argillite or slate with 1 to 3-centimetre beds of grey to black chert.

ROAD RIVER GROUP (OSDRR)

Gabrielse *et al.*, (1973, 1977) extended the name Road River Formation into the Selwyn Basin and then into the Northern Rocky Mountains from its type locality in the Yukon. There, it was first used to describe Lower Cambrian to Lower Devonian strata in the Richardson Trough (Jackson and Lenz, 1962). The usage in this report follows that of Gordey and Anderson (1993) whereby the unit is raised to group status. This reflects the two major subdivisions of this package in the study area which are broadly equivalent to the two formations recognized in the Nahanni map area (Duo Lake and Steele formations).

The two units of the Road River Group recognized in this study are: a lower succession of Ordovician to Early Silurian black slates with lesser limestone and chert; and a succeeding section of Siluro-Devonian dolomitic siltstone with minor limestone and chert. An enigmatic package of slate, calcareous slate and limestone informally referred to as the 'Kitza Creek Facies' is provisionally included with the Road River Group. Sections of the lower Road River

Group were recognized in only a few localities; usually this package is grouped with the dolomitic siltstone unit.

In the southern part of the map area, the Road River Group primarily outcrops along a narrow, complexly folded and faulted belt along the footwall of the Split Top Mountain thrust fault. This band widens northward, such that between Terminus and Chee mountains the Road River Group is the most areally extensive rock unit exposed. These rocks then disappear below the Chee Mountain thrust fault and reappear east of Boya Hill. They may also crop in the lower Red River and Kitza Creek areas. No Road River Group strata were recognized farther north on the Liard Plain.

Lower Road River Group (OSRR)

The lower Road River Group generally forms a thin, recessive slaty succession through most of the map area. Sections within it closely resemble the upper Kechika Group. As a result, this unit is usually not mappable within the study area and is combined with the either the upper Road River or Kechika groups.

Complete sections of Ordovician Road River strata are confined to the southern part of the project area. Approximately 125 metres of this unit is exposed along the footwall of the Netson Creek thrust, some 5 kilometres east of Split Top Mountain. Upwards of 160 metres of Ordovician black slates are also reasonably well exposed along the top of the same thrust panel, several kilometres further east. This sequence is only sporadically recognized; it thins to 115 metres immediately south of Bluff Creek and only 50 metres are well exposed on the ridge north of the creek. Poor exposures farther north along this thrust panel also suggest a thickness of only 50 metres.

Slates that can be confidently assigned to this unit crop out in only a few other localities in the map area. Lower Road River black slate is structurally interleaved or infolded with Road River siltstone and Kechika slate immediately

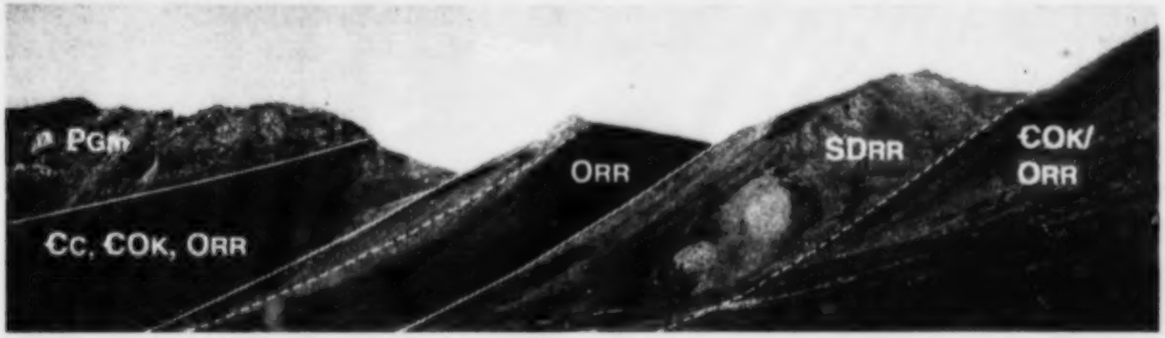


Photo 38. Looking north at the head of the valley immediately east of Gataga Mountain where an imbricated section of Kechika (ЄOK) to Road River (SDRR and OSRR) lithologies is exposed in the footwall of the Gataga Mountain thrust fault below the Gataga Volcanics. This

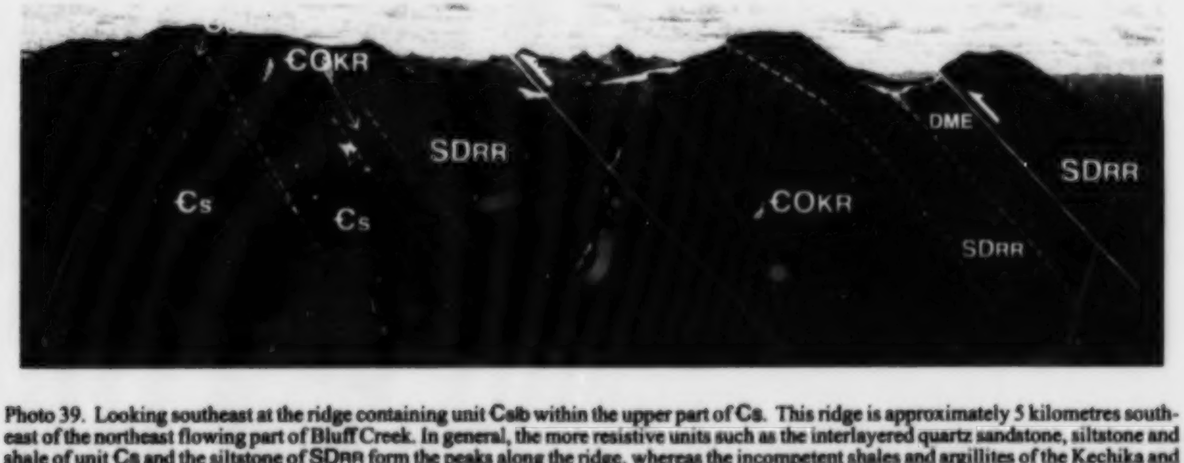


Photo 39. Looking southeast at the ridge containing unit Єsb within the upper part of Єs. This ridge is approximately 5 kilometres southeast of the northeast flowing part of Bluff Creek. In general, the more resistive units such as the interlayered quartz sandstone, siltstone and shale of unit Єs and the siltstone of SDRR form the peaks along the ridge, whereas the incompetent shales and argillites of the Kechika and lower Road River groups (ЄOKR), and Earn Group (DME) occupy the saddles. Also visible in this photograph is the section of black slate above Єsb and below rocks assigned to ЄOKR. No thick, clean carbonate belonging to unit Єc is found in this section.

east of Gataga Mountain in the footwall of the Gataga Mountain thrust. This structural imbrication becomes less complicated some 5 kilometres to the northwest, where 50 to 75 metres of Ordovician black slates, siltstones and carbonates separate Kechika slates and Road River siltstones in the immediate footwall of this thrust fault. Middle and Upper Ordovician slates, with interbeds of baritic limestone, are exposed in the centre of the map area, approximately 2 kilometres south of the first big bend in Matulka Creek, along a creek that cuts the western overturned limb of a syncline. This section appears to be several hundred metres thick, although this is probably the result of structural thickening. It also contains lithologies typical of the Kechika Group. Lower Road River black slates crop out within the core of the northeast-verging syncline east of Brownie Mountain. These continue northwestward to the headwaters of Matulka Creek where they are cut by a thrust fault. To the north, these rocks cannot be distinguished from those of the Kechika Group.

Elsewhere it is difficult to separate slates of the lower Road River from those of the Kechika Group and they have been grouped together in many cases (*see* previous section). The weathering characteristics and overall lithology of these slates and siltstones is also very similar to those of the Earn Group, making it difficult to differentiate between them, especially in isolated outcrops or where intervening, stratigraphically younger Road River rocks are poorly exposed. This is particularly true in the low-relief area northwest of Brownie Mountain and east of Split Top Mountain, where a series of tight folds and related faults repeat Road River dolomitic siltstone and Earn Group lithologies. It is possible that some of the poorly exposed lithologies assigned to the Earn Group are misrepresented lower Road River Group. Biserial graptolites, which only occur in the Road River slates, are helpful in resolving this problem.

A narrow, relatively poorly exposed belt of slates, some 5 kilometres north of Terminus Mountain, best illustrates this problem. The section is composed of blocky to splintery, dark grey to black, sooty slate and argillite to siliceous argillite in beds up to 20 centimetres thick. The rocks high(?) in the section are locally interlayered with well bedded to nodular, dark grey to black argillaceous limestone. Slate and silty slate associated with these limestone layers also contain horizons of nodular barite up to 50 centimetres thick. Superficially, particularly taking the baritic horizons into consideration, these rocks resemble the Earn Group and were initially mapped as such (Ferri *et al.*, 1996b). Subsequently conodont identification indicated an Early Silurian age, placing them within the lower Road River Group. This relatively thick section of argillite is atypical of lower Road River Group sections in the map area.

The basal part of the Road River Group is typically composed of graptolitic, dark grey, blue-grey and black shiny graphitic slate and siliceous slate to siltstone (Photos 38, 39). Slates of the lower Road River and Kechika groups appear conformable where observed. The slate is commonly soft and friable, although resistant layers of dark grey to black graphitic chert and siliceous argillite locally form layers 1 to 5-centimetres thick in the upper 5 to 10 metres of the unit. Slaty sections may contain thin, paler grey bands or laminations. Grey-brown and orange-weathering graded siltstone, up to 2 metres thick, and thin, grey, tan to orange-weathering, thin planar-laminated limestone beds are less common lithologies within this slate succession. Some siltstone layers are graded and intercalated with beds of buff to orange-weathering calcareous slate to silty limestone or dolostone up to 3 centimetres thick. These carbonate horizons may contain tiny (0.1 to 5 millimetres) authigenic barite crystals. Thin (1 to 2 centimetres) sandstone beds were observed very locally.

The lower Road River Group is poorly represented north of Trail Creek. Rocks interpreted to be lower Road River form several exposures south of Horneline Creek, although lack of fossil or structural control makes it impossible to rule out these rocks being part of the Earn Group. In these areas, lower Road River rocks characteristically consist of dark grey to bluish grey carbonaceous black shale, siliceous shale to argillite, siltstone, cherty siltstone to chert and grey to bluish grey limestone. Beds are up to 30 centimetres thick. Interlayered cherty argillite and chert, with lenticular bodies of limestone, are locally developed. On Horneline Creek, possible lower Road River rocks are composed of sooty black slate with interbeds of black argillite, and pale grey slate to silty slate. Lack of fossil data precludes separation of these rocks from the remainder of the Road River Group.

The lower Road River Group, together with underlying Kechika rocks, thin southward and are apparently not present below the Silurian siltstone unit throughout much of the southern map area. Omission of these units may be due to a sub-Silurian siltstone unconformity in the southern Kechika Trough, as theorized by Gabrielse (1981), or may be due to a condensed sequence coupled with the inability to recognize these recessive units in this poorly exposed terrain. This problem is discussed in more detail in the section on the Kechika Group.

Silurian Siltstone (SDRR)

The thickness of the siltstone unit of the Road River Group also varies significantly over the map area. No sections were measured, but structural interpretations indicate thicknesses ranging from 200 metres in the southeast to possibly 1000 or more metres in the north. Structural thicknesses tend to be smaller along the top of the Netson Creek thrust panel. They range from 200 to 300 metres in the Split Top Mountain area, to 400 metres east of Brownie Mountain and approximately 250 metres south of Netson Lake. Thicknesses ranging from 550 to 700 metres were deduced for the next poorly exposed section west of this panel. The large expanse of Road River siltstone between Matulka Creek and Chee Mountain may reflect this increased thickness, together with the effects of low-amplitude folding and moderate faulting. At one locality south of the headwaters of Horneline Creek, Earn lithologies rest above only some 100 metres of Silurian siltstone, suggesting rapid thickness variations.

Resistant, buff-orange weathering, grey to greenish grey, bioturbated dolomitic siltstone is the dominant member of the upper Road River Group (Photos 39, 40). Compositionally, this is the most uniform unit in the map area. This lithology is commonly referred to as the 'Silurian

Photo 40. Typical outcrop of grey to orange-weathering, bioturbated dolomitic siltstone ('Silurian Siltstone') of the upper part of the Road River Group. This exposure is in the footwall of the Gataga Mountain thrust, approximately 5 kilometres southeast of Terminus Mountain.

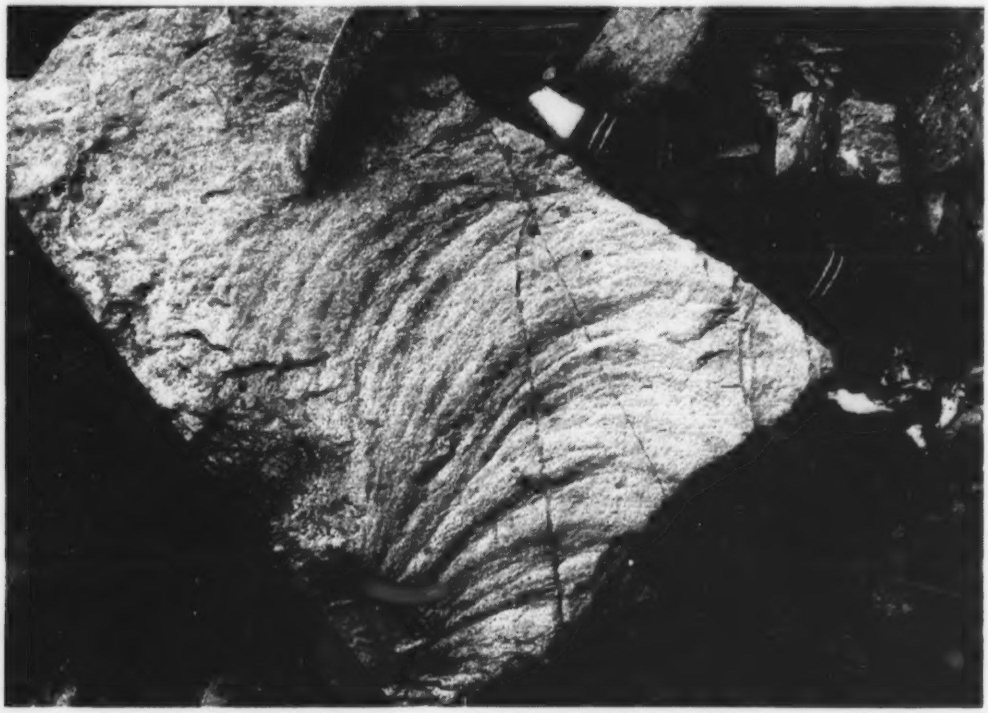


Photo 41. Picture of *Zoophycus*(?) trace fossil in dolomitic siltstone of the Road River Group. These fossils are very common in the Gataga Mountain area.

Photo 42. Typical bedding-parallel trace fossils in dolomitic siltstone of the Road River Group.

siltstone', although Early Devonian conodonts have been recovered from its upper part. It is relatively competent compared to the other basinal facies in the area and tends to form the ridges in the more subdued terrain north of Matulka Creek. Complete sections of this unit are not well represented and are only found underlying the high ground east of Split Top Mountain.

The dominant siltstone lithology is thin to thickly bedded or massive. It is commonly bioturbated, producing a mottled or wispy texture due to the disruption of laminae, which makes recognition of bedding difficult except in thick-bedded shale and siltstone intervals. In many outcrops bedding is discerned from subtle colour variations reflecting changes in argillaceous or dolomite content (Photo 40). Partings are typically blocky, although, in the absence of bioturbation, the relatively planar stratification produces platy to flaggy outcrops. Monoserial graptolites are typically preserved within these flaggy, non-bioturbated successions. In addition, several trace fossils were observed. The most common type is a series of overlapping, oval, dish-like impressions on bedding surfaces, tentatively identified as *Zoophycus*. They are open at one end, marked by concentric ridges, and up to tens of centimetres wide (Photo 41). Less common are worm casts, 0.5 to 1 centimetre thick, either inclined or perpendicular to bedding (Photo 42). Sediment infills of these tubes or burrows provide a useful top indicator where visible in cross-section.

Slates of the lower Road River Group are gradational into overlying Silurian siltstones over an interval ranging to tens of metres thick. The upper parts of the Ordovician lower Road River slate sequence contain paler grey slate to silty slate bands which become thicker with more silt up-section and exhibit a mottling typical of the overlying siltstones. The basal part of the Silurian siltstone locally contains sections of grey, nondescript slate and silty slate more than 100 metres thick. Grey slates and siltstones in the footwall of the Split Top Mountain thrust fault have been assigned to the upper Road River Group because they are on strike with typical Road River lithologies to the northwest. Thin-bedded orange-weathering planar-laminated, flaggy limestone to silty limestone is locally developed. Buff-weathering, grey, wavy laminated to thinly layered limestone locally forms metre-thick sections within this unit in the central part of the map area.

Minor lithologies include grey limestone, grey to grey-brown banded chert, and fine to very fine grained, grey to dark grey quartz sandstone to quartzite. Local recessive beds of grey to dark grey argillite to silty argillite are gradational into enclosing siltstone. Just northwest of Gemini Lakes, grey dolomitic siltstone is associated with blocky black argillite and grey, fetid bioclastic limestone containing crinoid ossicles, rugose corals, bryozoa and shell fragments occurs in an isolated outcrop. Their association with typical upper Road River lithologies is uncertain.

The top of the siltstone section is locally marked by a limestone-chert couplet from 5 to over 20 metres thick. These subunits are best developed south of Horneline Creek, although sections in the Kitza Creek area are similar. In many localities this unit is immediately overlain by siltstones and slates of the Earn Group. This, together with its distinctive character, makes it an excellent marker unit. The stratigraphic order of chert and limestone appears to vary, with chert generally succeeding limestone between Brownie Mountain and Horneline Creek whereas the opposite occurs southwest of Brownie Mountain.

In the south, the chert-limestone succession is 10 to 15 metres thick (Photo 43). Dark grey-brown, grey and white, thin to thickly bedded chert, with interlayers of dark grey cherty argillite, comprises the basal 2 to 3 metres of this sequence. Approximately 1 to 2 metres of thin to moderately bedded, cream to light grey weathering, grey, silty to argillaceous micritic limestone, interlayered with thin beds of typical Silurian siltstone, are exposed 1 to 2 metres above the chert sequence. Several metres of orange-weathering, bioturbated siltstone succeed this limestone sequence and grade into overlying lithologies of the Earn Group across a stratigraphic thickness of 50 centimetres.

North of Brownie Mountain, the sequence is over 20 metres thick and the sections of typical dolomitic siltstone are absent. The limestone is micritic and dolomitic, grey to buff weathering, dark grey to grey-brown, and up to 20 metres thick. It commonly displays faint laminar bedding traces and breaks into blocky or platy pieces from 1 to 20 centimetres thick. It is locally argillaceous and has a slightly

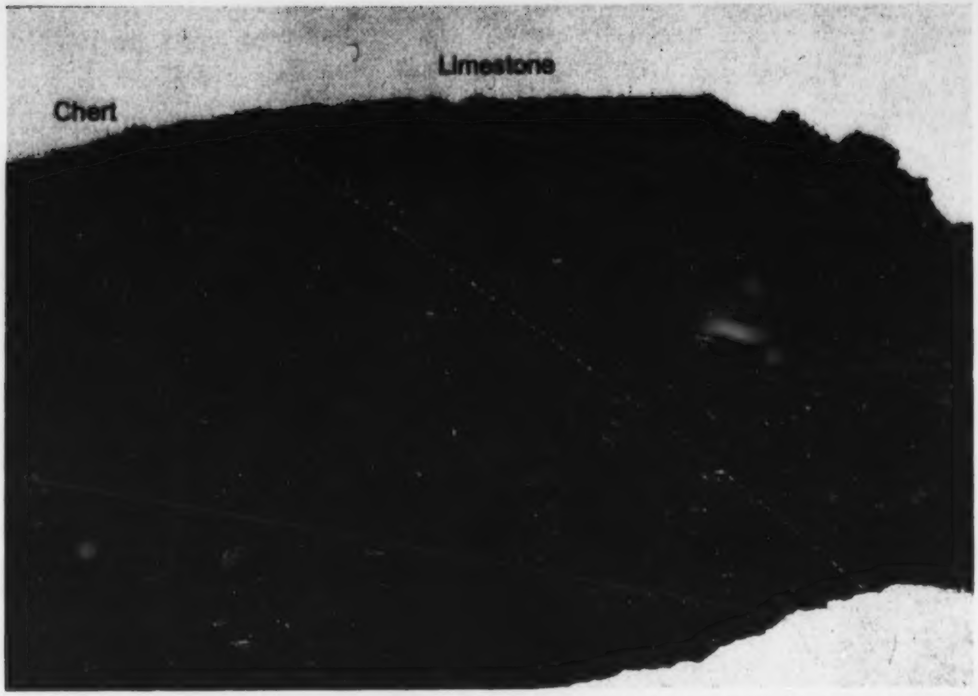


Photo 43. The hammer is lying on grey to brown chert which is overlain by thinly interlayered limestone, all of the uppermost Road River Group. Dark argillite and shale of the Earn Group is exposed only a few metres to the right of the limestone. This locality is along a ridge top some 3 kilometres southeast of the northeast-flowing part of Bluff Creek.

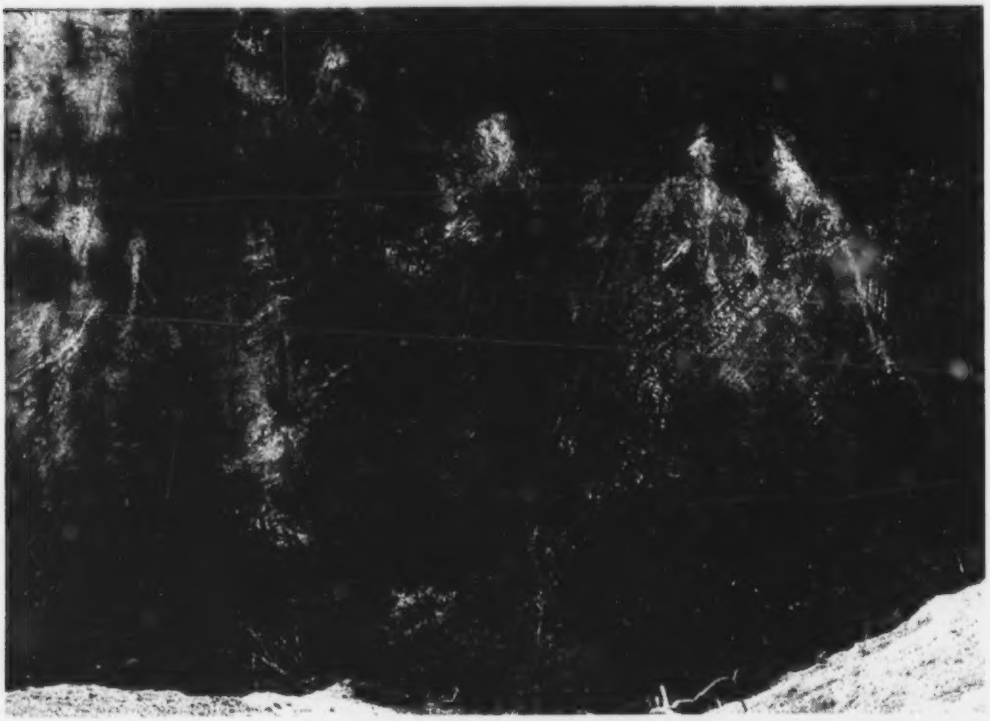


Photo 44. Strongly folded and faulted calcareous argillite, siltstone and slate along the lower parts of Horneline Creek. These rocks have been tentatively assigned to the Kechika Group, but have characteristics similar to lithologies found in the Kitza Creek area.

fetid odour when broken. Like the overlying chert member, the limestone also contains 1 to 5-centimetre interbeds of argillite to cherty argillite.

Chert to argillaceous chert, up to 2 metres thick, is typically found above the limestone, although they are interlayered in some localities. Chert is pale grey to black or orange-brown to maroon in colour. Bedding is planar to very poorly developed, with beds ranging from 1 to 50 centimetres thick. This unit is commonly shot through with tiny quartz veinlets and has blocky to platy partings.

On the east side of the Kechika River, just south of the confluence with the Red River, limestone at the top of the Silurian siltstone is followed by several metres of massive, grey, calcareous quartz sandstone with well rounded, spherical quartz grains. This sandstone is succeeded by 10 to 15 metres of sooty, dark grey to black slate to argillite with thin beds of dark grey calcareous argillite to limestone. Slate and argillite become limier up section and the uppermost part is composed almost entirely of thick-bedded to massive, sooty and fetid, very fine grained, limestone to argillaceous limestone. These calcareous rocks are estimated to be 15 to 20 metres in thickness and are succeeded conformably by Earn lithologies. A very similar sequence of argillite, slate and partly oolitic limestone is found along the Kechika River, north of its confluence with the Gataga River. This fault-bounded section is of similar stratigraphic thickness and is interpreted to be along strike from Earn rocks. Both these sections contain Middle Devonian fauna.

Kitza Creek Facies (ODRK)

Around Kitza Creek, there are mappable areas of Silurian siltstone of the Road River Group, and also substantial areas of dark grey to black, carbonaceous calcareous siltstone, silty limestone, siltstone, argillite, slate, sandstone and chert. The stratigraphic position of the latter group of rocks is not clear because fossil control is very poor, and contact relations with the Road River have not been observed. Although the slates and argillites resemble those of the Earn Group, the associated abundant calcareous material is not typical of the Earn regionally and is more characteristic of Road River lithologies in the southern Kechika Trough (Gabrielse, 1981; MacIntyre, 1992, 1998). These rocks are tentatively assigned to the Road River Group, although limited control does not rule out the possibility that some may be older or younger .

Kitza Creek rocks are characterized by dark grey to black, carbonaceous siltstone to silty argillite and shaly slate (Photos 44, 45, 46). All may be calcareous to varying degrees and be interlayered with thinly to thickly bedded buff, pale to medium grey weathering, dark grey to black, silty to argillaceous fetid limestone. Limestone is platy to blocky and poorly cleaved, and in some sections is quite thick, forming prominent topographic ribs. Thin layers of grey-weathering, calcareous quartz sandstone to sandy limestone and pale grey calcareous tuff are associated with these lithologies. The sandstones consist of rounded quartz grains, and argillite and carbonate clasts. Sandstone horizons can be massive and several metres thick. Quartz wacke or quartz-carbonate clastic horizons are found locally. Limestone is also seen with thinly laminated, orange to brown-weathering, grey dolomitic siltstone. Calcareous and siliciclastic rocks are locally interbedded with medium bedded, dark bluish grey to black chert. In one locality, these rocks are associated with debris flows composed of angular chert clasts and limestone intraclasts that are up to cobble size. Elevated barium concentrations are present in argillaceous limestone at one locality on Kitza Creek.

Photo 45. Folded, interlayered, dark grey argillite and tan to buff-weathering siltstone to dolomitic siltstone assigned to the Kitza Creek facies along the south bank of the lower Red River. These rocks are also characterized by a conspicuous banding, as shown here.

Photo 46. Dark grey to black calcareous argillite and argillite interlayered with white-weathering, thin to thickly bedded argillaceous limestone assigned to the Kitza Creek facies along the north bank of the lower Red River. Kitza rocks are commonly distinguished by conspicuous bands of white-weathering limestone.

Rocks similar to the Kitza Creek facies crop out along the Red River and along the lower parts of Horneline Creek (Photos 44 to 46). Contact relationships with surrounding units in both localities are obscured or faulted. On the Red River, calcareous argillites and limestones (Photo 46), similar to those near Kitza Creek, are associated with rusty weathering, dark grey to black, carbonaceous slate or argillite with interbedded thin laminae or wispy layers of tan to buff-weathering dolomitic siltstone. The dolomitic horizons give the rock a characteristic striped appearance (Photo 45). Siltstone layers are from 0.1 to 10 centimetres thick and comprise up to 50 per cent of the rock. The dark grey to black argillites and slates resemble those of the Earn Group, but the dolomitic siltstones are more characteristic of the Silurian siltstone. This suggests these rocks may be part of the upper unit of the lower Road River Group, transitional into the Silurian siltstone unit.

Age and Correlation

Graptolites collected 2 kilometres west of Terminus Mountain are from the lowermost part of the Ordovician Road River, approximately 1 metre above its lower contact. The collection consists of early to middle Arenig graptolites (*T. akzharensis* Zone, *P. fruticosus* Zone or possibly the lower part of the *D. bifidus* Zone; B.S. Norford, personal communication, 1995). Fossil collections made from the lower Road River Group elsewhere in the map area indicate a Llandeilan (late Middle Ordovician) lower age range, although the apparently conformable contact commonly seen with underlying slates of the Kechika Group also suggests they are as old as Early Ordovician. South of Bluff Creek, Ashgillian to Wenlockian (late Late Ordovician to late Early Silurian) conodonts were recovered from the Silurian siltstone, several metres above its gradational contact with lower Road River slates, and indicate a late Early Silurian upper age range for these slates. North of Terminus Mountain, rocks assigned to the lower Road River Group yielded Llandoverian (earliest Early Silurian) conodonts.

Dolomitic siltstone within the Silurian siltstone unit ranges in age from late Early Silurian (Llandoverian) to late Early Devonian (Emsian) based on its stratigraphic position above uppermost lower Road River slates and below the chert-limestone marker. Calcareous black slate, limestone and sandstone at the top of the Road River Group contains Middle Devonian (early(?) Eifelian) and Middle to ?Late Devonian (Eifelian-?Frasnian) conodonts (Table 3).

Road River Group lithologies, particularly the Silurian siltstone unit, are widespread within the Kechika and Selwyn basins. Gabrielse (1981), Gabrielse *et al.* (1977), MacIntyre (1980b, 1981b, 1992; 1998), McClay *et al.* (1988) all describe a bioturbated dolomitic siltstone unit of broadly Silurian age in the southern Kechika Trough. Cecile and Norford (1979), in Ware, east half, describe a Siluro-Devonian succession of dolostone, siltstone, shale and sandstone which is probably a more proximal equivalent of this unit. Lower Road River Group rocks in the southern Kechika Trough are dominated by deep-water shales and limestones and are broadly similar to those of the map area, although there are differences due to the proximity of some areas to the margin of the Paleozoic carbonate platform. Rocks of the study area are, for the most part, restricted to deeper, more distal parts of the Kechika Trough resulting in thinner, more argillaceous deposits than seen elsewhere.

Early to Middle Devonian chert, limestone, calcareous slate and sandstone found above the Silurian siltstone unit are similar in age and character to Early Devonian rocks informally referred to as the Paul River formation in the southern Kechika Trough (MacIntyre, 1998). The base of the Paul River formation consists of a thin unit of black chert and dolomitic mudstone, siltstone and limestone which, in the deeper parts of the basin, is overlain by grey calcareous siltstone and black silty shale. This succession is followed by quartz wacke and sandstone along the eastern margin of the southern Kechika Trough, close to the carbonate platform. This unit is followed, in turn, by limestone debris-flows and black shales (MacIntyre, 1998). This latter sequence becomes finer grained and thins away from Early to Middle Devonian limestone buildups represented by the Kwadacha, Akie and Pesika reefs (MacIntyre, *ibid.*). This succession, particularly the sandstone and limestone debris-flows, bears strong similarities to sandstone, slate and calcareous slate exposed at the top of the Road River Group immediately south of the mouth of the Red River. This, together with local bioclastic deposits within Silurian siltstone, suggests that upper Road River deposition in the northern-most Kechika Trough was closer to carbonate buildups representing either isolated linear reefs or the western edge of paleo-platform carbonate deposition.

In the Selwyn Basin, rocks of the Road River Group are widespread and are dominated by shale and chert facies. Those equivalent to the Silurian siltstone unit crops out in the Watson Lake map area (unit Ss; Abbot, 1981) and in the Nahanni map sheet (Steele Formation; Gordey and Anderson, 1993). Similar rocks are extensively exposed in the northern Cassiar platform (Gabrielse, 1963; Nelson and Bradford, 1993).

The exact age of the Kitza facies is not known. Early Late Ordovician (Caradocian) graptolites are reported from rocks presently assigned to typical Road River lithologies (Miller and Harrison, 1981a). The lithological make-up of this unit suggests that it is probably part of the Road River Group, although, considering the limited amount of exposure in the area, parts could be younger or older. Horizons of quartz-rich limestone debris suggests units in the Kitza Creek area were deposited proximal to carbonate buildups or the ancient carbonate platform, as suggested for the northern parts of the Road River Group in the map area (*see* above). This could easily explain the complexity and uniqueness of many of the units present in this region. Our mapping south of this area was concentrated within what was the most basinal part of the Kechika Trough during Road River time. Consequently, units are distal, condensed and dominated by shale. The character of the Road River Group changes dramatically close to flanking carbonate buildups. This is well documented in the southern Kechika Trough where there is a marked increase in thickness, and the amount of coarse clastics and carbonate, toward coeval platform carbonates (MacIntyre, 1998). Lithologies within the Kitza facies bear many similarities to units within the Road River Group along the eastern margin of the southern Kechika Trough (MacIntyre, 1998), particularly the relatively abundant quartz sandstone, carbonate and lesser lithologies, such as conglomerate and tuff. The poor exposure in the Kitza Creek area, coupled with limited control points, does not allow subdivision of these rocks or confident stratigraphic placement relative to the Silurian siltstone unit.

One of the dominant lithologies of the Kitza facies, a sequence of interbedded calcareous argillite and limestone (Photo 46) exposed in the Kitza Creek, Red River and Horneline Creek areas, bears some resemblance to lower Road River lithologies mapped by Gabrielse (1981) in the Paul River region of the southern Kechika Trough.

EARN GROUP (DMe)

Black slate, siltstone, chert and minor sandstone, limestone and conglomerate of late Middle Devonian to early Mississippian? age in the map area are assigned to the Earn Group. The name was first proposed by Campbell (1967) in the northwestern Selwyn Basin and extended southward by early workers in the Gataga district, who noted the striking similarity between Devono-Mississippian strata of the Kechika and Selwyn basins (Jefferson *et al.*, 1983; Pigage, 1986; MacIntyre, 1992, 1998; Gordey *et al.*, 1982).

In the southern Kechika Trough, the Earn Group has been subdivided into three informal units: blue-grey weathering siliceous argillite of the Middle to Upper Devonian Gunsteel formation; rusty weathering, soft grey shale of the Late Devonian to Early Mississippian Akie formation; which grades laterally into chert-quartz siltstone, sandstone and conglomerate of the Warneford formation (MacIntyre, 1992, 1998; Pigage, 1986; Jefferson *et al.*, 1983). Although these three lithological variations were recognized in the map area, it was not possible to map out the individual facies. This is due not only to the poor exposure of this succession, but also to the apparent interfingering of the various lithologies.

A structurally thickened section of Earn and Road River rocks extends from the Gataga River, immediately east of Split Top Mountain, northwestward to the headwaters of Matulka Creek. This zone widens northward, such that Earn rocks are confined primarily to synclinal cores within Road River rocks. The unit is well exposed along ridges in the southern part of the map area, whereas to the north, topography becomes more subdued and the best exposures are in creek valleys. A particularly good section occurs along a north-flowing creek about 5 kilometres north of Terminus Mountain. Earn rocks are also found in the footwall and hangingwall of the Split Top Mountain thrust fault. More limited exposures of the Earn Group are mapped along the lower parts of Bluff Creek, along the footwall of the Netson Creek thrust, south of Horneline Lake and as small outliers between Gemini Lakes and the Kechika River. Sections of the Earn Group are believed to occur along the Red River, although differentiating them from rocks of the Road River Group was not possible.

The true thickness of this succession was not determined in the map area because the upper contact was never found. A minimum of 600 metres is inferred along poorly exposed slopes south of Netson Lake. Structural sections suggest at least several hundred metres are present in thrust panels and folds between Brownie Mountain and Matulka Creek.

The Earn Group is composed of grey to blue or silvery blue-grey weathering, dark grey to black, carbonaceous fissile shale to siliceous shale and slate (Photo 47). Sequences of blocky grey to dark grey, sooty argillite to siltstone and siliceous argillite or chert are found within this shaly succession. All these rocks have a characteristic yellowish stain on weathered surfaces. Blocky argillaceous to silty sections contain 1 to 20-centimetre beds with thin interlayers of shale and, higher in the sequence, display light to dark grey colour banding. Less siliceous shale or slate sections are recessive and appear to be present throughout the sequence. Slate is quite fissile to splintery, and very locally contains nodules of radiating barite crystals up to several centimetres in diameter. Bedding is planar to wavy, and is generally accompanied by slaty cleavage except in chert, siltstone and some argillites. Sections of grey to dark grey to rusty weathering,

Photo 47. Typical section of dark grey to dark blue-grey weathering argillite, shale and siltstone of the Earn Group exposed several kilometres north of Bluff Creek.

sooty slate, with lustrous cleavage planes, crop out along the middle part of Bluff Creek.

Limestone, although rare in this fine clastic sequence, forms conspicuous sections when present. Limestone is grey to dark grey weathering, grey to black and argillaceous. It is nodular to well bedded (beds 1 to 30 centimetres) and forms sections up to 2 metres thick. A 2 to 3-metre section of grey-weathering, grey to dark grey, slightly argillaceous limestone with 1 to 10-centimetre argillaceous partings is exposed several kilometres north of Bluff Creek.

Dark grey to rusty weathering, dark grey, granule to pebble conglomerate was noted in one locality towards the top of the Earn succession south of Bluff Creek. Clasts consist predominantly of subrounded to well rounded, light to dark grey chert and mono- to polycrystalline quartz with lesser sandstone, quartz wacke, slate, siltstone and rare feldspar fragments. This bed is 1.5 metres thick and exposed for 15 metres along strike.

Local, less siliceous slate to silty slate and siltstone in the upper parts of Earn sections may be equivalent to the Akie facies of the southern Kechika Trough. Coarser siliciclastics were mapped in the Earn Group locally, such as those exposed along a steep-sided, north-flowing tributary of Davie Creek. This section consists of interlayered, finely laminated to crosslaminated, brown to buff-weathering, grey siltstone to very fine grained sandstone and dark grey to black fissile slate, up to 10 metres thick. Siltstone/sandstone horizons are 0.1 to 30 centimetres thick and are faintly micaceous on bedding surfaces. These coarser lithologies may be distal tongues of the Warneford facies which, in the southern Kechika Trough represents westerly derived clastics in the upper part of the Earn Group (MacIntyre, 1992; 1998).

One of the characteristic features of the Earn Group in the Gataga district is the presence of red to orange limonitic seeps which locally cement glacial and soil material forming a ferricrete deposit or pavement (Photo 48). These deposits are numerous and easily seen from the air in the high alpine country south of the map area, but are more difficult to locate in the more subdued and wooded terrain covered by our mapping. Several are well exposed on the south side of Bluff Creek and numerous other occurrences were found in creek valleys and slopes underlain by the Earn Group south and east of Netson Lake.

The lower part of the Earn is dominated by shale, siliceous shale and slate which regionally hosts significant deposits of bedded barite±pyrite±sphalerite±galena (Photo 49). Several occurrences of stratiform or nodular barite and pyrite are found within the lower part of the Earn Group inside the project area. Stratiform or bedded barite up to several metres thick is commonly calcareous and grades into silty baritic limestone. The limestone and baritic units sometimes have thin interlayers, lenses or nodules of dark grey to black chert. In the southeastern part of the map area, barite is also associated with finely laminated, grey to dark grey siltstone or mudstone of possible turbidic origin.

The contact between Road River and Earn rocks was observed in only a few localities and appeared to be relatively abrupt, but conformable. In two localities south of Bluff Creek, grey siltstone immediately above chert and limestone at the top of the Road River Group gives way to dark grey slate and siltstone of the Earn Group. In another locality, the limestone-chert marker is not developed, and dolomitic siltstones of the Road River Group are abruptly, but conformably, succeeded by slates and siltstones of the Earn Group. This section is exposed along the western limb of an easterly overturned syncline approximately 1 kilometre upstream from the mouth of the large creek flowing west into Matulka Creek.

Photo 48. Rusty coloured limonitic staining found on Earn Group rocks exposed on southeast flowing creek, approximately 4 kilometres north of Bluff Creek. These limonitic stains are quite common in rocks of the Earn Group and commonly are anomalous in metals such as zinc and nickel.

Age and Correlation

Few fossils were found in Earn Group rocks within the map area and these only indicate a Middle to Late Devonian age range. Earn rocks sit stratigraphically above Eifelian (early Middle Devonian) strata of the Road River Group, giving a maximum lower age range for these rocks. In the southern Kechika Trough, lower Earn Group rocks are believed to range down to the late Middle Devonian (latest Givetian; MacIntyre, 1998; Irwin and Orchard, 1989). Brown-weathering siltstones, slates and fine sandstone north of Terminus Mountain are similar in character to rocks of the Warneford formation of the southern Kechika Trough, which ranges into the Mississippian (MacIntyre, 1998). Syngenetic barite mineralization could not be accurately dated in our study area. To the south it is Fammenian

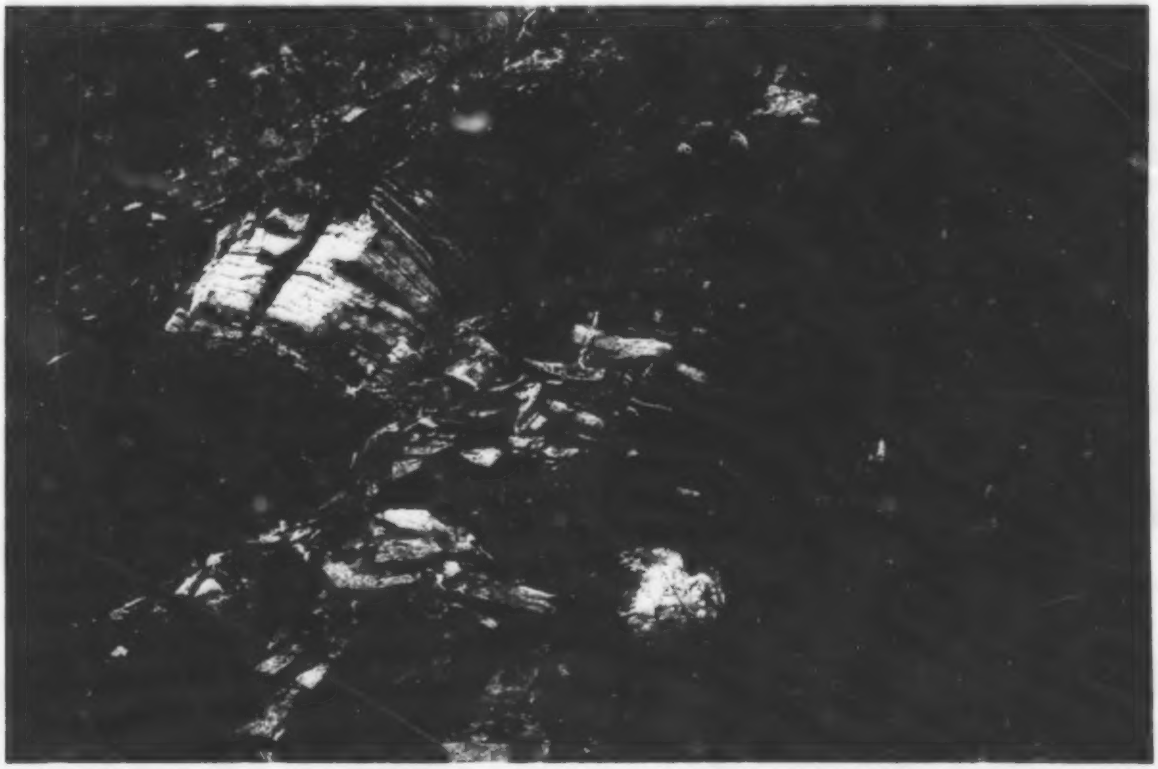


Photo 49. Light grey weathering, massive bedded barite or witherite within lower Earn Group rocks. Although these barite-rich horizons can be traced for several kilometres, locally, as shown here, they form lensoidal bodies only a few metres in length.

(latest Late Devonian; MacIntyre, 1992, 1998; Irwin and Orchard, 1989; Paradis *et al.*, 1998). From these data, the Earn Group is believed to be Middle Devonian to Mississippian in age.

The Earn Group in the map area is dominated by fine-grained and siliceous rocks similar to the Gunsteel formation of the southern Kechika Trough (MacIntyre, 1998) and the Portrait Lake Formation of the southeastern Selwyn Basin (Gordey and Anderson, 1993). The other members of the Earn Group were seen locally within the map area but could not be differentiated due to poor exposure. These include coarse clastics equated with the Warneford formation in the south or the Prevost Formation of the Selwyn Basin. Brown-weathering slates and siltstones, informally referred to as the Aikie formation in the southern Kechika Trough, and grouped with the Prevost Formation in southeast-central Selwyn Basin, were also seen in several localities.

The Earn Group, and its equivalents, comprise a eastwardly prograding basinal sequence found throughout most of the ancestral North American miogeocline of western Canada. It can be traced from northern Yukon (Canol, Imperial and Tuttle formations: Norris, 1985; Earn Group: Campbell, 1967; Gordey *et al.*, 1982; Gordey and Anderson, 1993), into the southern Kechika Trough (MacIntyre, 1998) across into the Cassiar Terrane (Nelson and Bradford, 1993; Big Creek Group: Ferri and Melville, 1994; Black Stuart Group: Struik, 1988) and eastward onto the ancient miogeoclinal platform (Besa River Formation: Thompson, 1989).

These basinal rocks flooded eastward across the ancient platform, bringing carbonate deposition to a close and, in the process, erasing regional depositional elements which spanned much of early and middle Paleozoic time. Furthermore, the western part of this shale package contains northwestward and westward-thickening sections of coarse clastics (Prevost, Warneford and Guyet formations) which were sourced from the northwest and west, and not from the ancient craton to the east. The regional tectonic process behind this fundamental change in ancient miogeoclinal deposition is still the topic of much debate and a detailed examination of the various hypotheses is beyond the scope of this bulletin. There are two views on the significance of Earn deposition: one suggesting that these rocks are the result of extension, with coarse clastics derived from elevated blocks along the western miogeocline (Gordey *et al.*, 1987) and the other suggesting that these basinal rocks are part of a foredeep produced by contractional deformation (Smith *et al.*, 1993). In this latter scenario, coarse clastics would represent distal tongues of eroded material shed from thrusted terranes to the west.

MOUNT CHRISTIE FORMATION(?) (MPMC)

Approximately 5 kilometres south of the Liard River, some 5 metres of grey to buff-weathering, pale grey to dark grey and mottled, moderately to thickly bedded chert crops out along the top of a small knoll. Bedding is planar to wavy and there is extensive limonitic staining. Pale grey chert is also exposed along the top of Mount Earle. Thin and well bedded, pale salmon and green chert with pale green argillite partings also occurs stratigraphically above the Earn Group at the Roman showing along the Liard River (*see* Economic Geology section).

Age and Correlation

No significant sections of pale coloured chert have been seen in the Earn Group or older stratigraphy anywhere else in this mapping project, suggesting that these rocks are a different, younger unit. Thick sections of post-Earn chert have been described in the Selwyn Basin and assigned to the upper part of the Mississippian to Permian Mount Christie Formation (Gordey and Anderson, 1993). Farther east, in the Rocky Mountains, chert of similar age is included in the Permian Fantasque Formation (Bamber *et al.*, 1991). Pale red and green chert, of broadly Mississippian to Permian, age has also been described in the Cassiar Mountains (Nelson and Bradford, 1993) and may be a western equivalent of the Liard River cherts. Consequently, the sporadically exposed, pale coloured cherts in the northern part of the map area are tentatively assigned to the Mississippian to Permian Mount Christie Formation, in accordance with established Selwyn Basin nomenclature.

TUYA FORMATION(?) (TQT)

Massive to fragmental, fresh-looking basalt outcrops on several hilltops between Black Angus and Kloye creeks, approximately 10 kilometres southwest of the Liard River. These rocks are grey-weathering, dark grey-brown to dark green, aphanitic or plagioclase-olivine-phyric basalt (Photo 50). Basalt fragments may be vesicular, angular to subrounded and up to 30 centimetres in size; small pockets of black volcanic glass were also noted. The tuffaceous matrix displays a yellow to tan colour locally, indicating some alteration. It is not known if these volcanics are subaerial or subaqueous. Chemically they are high-silica basalts verging on basaltic andesites (Table 2). They are relatively high in alkalis, falling close to the dividing line between alkaline and subalkaline basalts as defined by Irvine and Barager (1971; Figure 11) and, based on an AFM plot, are calcalkaline in composition.

Age and Correlation

Pleistocene or Tertiary basalt has been described from the McDame (Gabrielse, 1963) and Jennings River (Gabrielse, 1969) map areas. The volcanics form prominent flat-topped volcanic cones in the Jennings River area and are grouped within the Tuya Formation. The basaltic rocks in our study area are similar to descriptions of Tuya Formation volcanics to the west and are grouped with them.

CASSIAR TERRANE (CA)

Several traverses were made westward across the Northern Rocky Mountain Trench, north of the Red River. West of Mount Monckton, strong shearing in grey, laminated phyllite is believed to reflect deformation in the fault zone. Immediately to the west, presumably in the Cassiar Terrane, rocks are quite variable and range from quartz-feldspar-bearing sandstone of Late Proterozoic age to siltstone of possibly Siluro-Devonian age. The medium

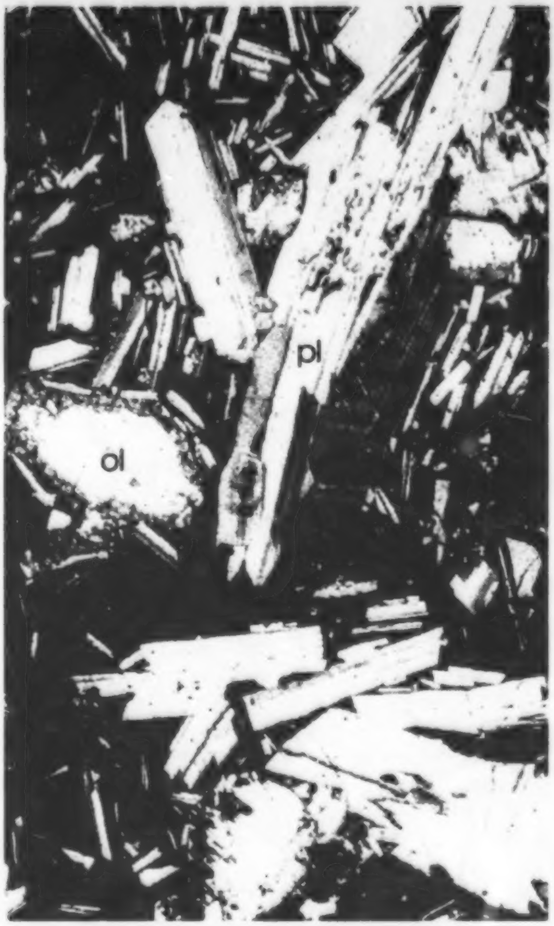


Photo 50. Photomicrograph of Tuya Formation basalts; long axis is 6 millimetres. Zoned plagioclase laths (pl) comprise the bulk of the phenocrysts. Olivine (ol), altered to red-brown indingsite along its rims, is the mafic mineral.

grey, moderately to thickly bedded quartz sandstone with rare feldspar clasts and phyllitic partings is most likely Late Proterozoic and belongs to the Ingenika Group. The affinities of the other rocks are more problematic due to lack of data. These include: grey to yellow or orange-weathering, grey to green, massive to finely laminated dolomitic siltstone, cherty siltstone and chert; yellow to orange, grey, faintly laminated silty limestone to calcareous siltstone; and grey, coarse-grained calcareous quartz sandstone to quartzite and grey slate. These lithologies may belong to the Road River, Kechika and Atan groups, respectively.

INTRUSIVE ROCKS

Intrusive rocks occupy a very minor portion of the map area. The most abundant are the relatively large bodies of gabbro within the Kechika Group exposed in the Gemini Lakes area. The remainder consist of small dikes and plugs. Intermediate to felsic intrusions on Boya Hill, although small, are economically significant as they are associated with tungsten-molybdenum mineralization.

GABBRO (ℙg)

Northeast of Gemini Lakes, gabbro forms several elongate bodies intruding rocks of the Kechika Group. It is orange-brown weathering, speckled green and white, unfoliated, equigranular and medium to coarse grained. Plagioclase is grey to pinkish and comprises between 40 to 50 per cent of the rock. The remainder consists of dark green pyroxene, hornblende and biotite. Intrusive relationships were seen in only a few outcrops, and in one it appears that the gabbro is a sill-like body.

Age and Lithologic Correlation

Gabrielse (1962a) described dikes and sills of gabbro in rocks of Proterozoic and early Paleozoic age, and suggested that they are no younger than Kechika age because they are never found intruding younger rocks (H. Gabrielse, personal communication, 1996). Our observations support this conclusion.

If this is correct, then magmatism was coeval with Kechika deposition. In the Tuchodi Lakes area, dikes and sills are seen within the Kechika Group which also contains thick sections of volcanics (Taylor and Stott, 1973). Mafic volcanics are also present in the Kechika Group in south-central Yukon, along the west side of the Cassiar Terrane (Gordey, 1981), in eastern Selwyn Basin (Gordey and Anderson, 1993) and in similar rocks in the Anvil Range along the west side of the Selwyn Basin (Gordey, 1983).

BOYA HILL INTRUSIVES (EKp)

Tungsten-molybdenum stockwork-skarn mineralization on Boya Hill is related to north-trending dikes and sills of texturally and mineralogically homogenous, fine to medium-grained quartz-biotite-feldspar porphyry (Moreton, 1984). Peatfield (1979a) also describes quartz porphyry dikes in the area. These porphyry intrusions are commonly altered, together with the surrounding clastic and carbonate succession (*see* section on Economic Geology). Sills are from 2 to over 100 metres thick, and traceable for up to 450 metres (Moreton, *ibid.*). These rocks were not examined in detail during our mapping and the following descriptions are taken from Moreton (1984) and Peatfield (1979a).

Modal analysis indicates that the quartz-biotite-feldspar porphyry is of tonalite to granodiorite composition. Phenocrysts comprise up to 65 per cent of the rock; the average is 35 per cent plagioclase and 13 per cent each of quartz and biotite. The unaltered rock has abundant potassium feldspar in the groundmass, in addition to quartz, plagioclase and biotite. Hornblende locally comprises up to 15 per cent of the phenocrysts. Quartz porphyry is leucocratic and only weakly porphyritic such that it locally appears aplitic. The groundmass typically contains abundant potassium feldspar and in some localities there are sparse potassium feldspar and biotite phenocrysts. Narrow dikes of both quartz-feldspar ±biotite porphyry with a dark purplish groundmass and, dark brown mafic rock of predominantly plagioclase composition with variable amounts of hornblende and biotite are also present in this area.

Age and Lithologic Correlation

The age of these intrusions is believed to be approximately 100 Ma (late Early Cretaceous) based on wholerock K-Ar dating of hornfelsed sediments and a quartz-feldspar granodiorite dike. Analysis of hornfelsed sediments returned a 100±3 Ma age (unpublished date; T.G. Schroeter, 1980). The granodiorite dike is 100±2 Ma (Hunt and Roddick, 1987). It is sericitized, but unmineralized and believed to post-date mineralization associated with the quartz-biotite-feldspar porphyry (Hunt and Roddick, 1987), although its composition is consistent with the mineralized intrusions.

These intrusive rocks are part of the mid-Cretaceous Selwyn Plutonic Suite, a group of high-level, discordant stocks of granite, granodiorite and quartz syenite found throughout the Omineca Belt of the Yukon (Woodsworth *et al.*, 1991; Gordey and Anderson, 1993). They were intruded between 88 and 114 Ma and are believed to have been formed by partial melting of the thickened continental crust in response to regional compression. As a result, these intrusions display strong S-type characteristics (Woodsworth *et al.*, 1991).

OTHER INTRUSIONS

Numerous felsic dikes and small stocks are exposed throughout the map area north of Chee Mountain. The exact age of these bodies is unknown, but their relatively fresh appearance suggests they are Cretaceous or Tertiary. Considering the late Early Cretaceous age for igneous activity in the Boya Hill area and the widespread early Middle Cretaceous granitic intrusions in the eastern Selwyn Basin, most of these rocks are probably Middle Cretaceous in age.

Kp

Several feldspar and quartz-feldspar porphyry dikes intrude the low-grade metamorphic rocks of the Aeroplane Lake panel, and also occur in the footwall of this thrust panel. The groundmass of these dikes is generally medium bluish grey and weakly calcareous. Phenocrysts are pink to orange-buff feldspar and brown biotite. These bodies are up to several metres across, and where observed have chilled margins and cut the fabric of the hostrocks.

Age

Their age is unknown but they may also be related to the Boya Hill intrusions, 10 kilometres to the southeast, in which case they would be late Early Cretaceous.

KTp, KTg

A small body of speckled grey, medium-grained granite or granodiorite (**KTg**) with subhedral quartz phenocrysts up to 2 millimetres in diameter is exposed several kilometres west of Mount Monckton. Fracture surfaces are coated with magnetite or hematite. An intrusion of pale yellow, altered quartz porphyry (**KTp**) crops out a few kilometres southeast of Mount Monckton.

Age

Rocks underlying Mount Monckton are strongly hornfelsed, indicating proximity to a large intrusive body. Several outcrops of intrusive rock were also found in the area, which is along the extension of the Northern Rocky Mountain Trench fault zone. Their undeformed condition suggests they are younger than the fault, making them no older than latest Cretaceous or Early Tertiary.

CHAPTER 3 STRUCTURE

Although the stratigraphy of the project area suggests periodic extensional or contractional tectonism between Late Proterozoic and middle Paleozoic time, intense eastward compression during the late Mesozoic produced the dominant structural fabric. This structural style is dominated by thrusting and/or folding and is part of several major fold and thrust structural provinces (Rocky Mountain and Selwyn, Figure 8) that together extend along the entire eastern margin of the North American Cordillera. Folding and thrusting are inter-related; most thrusts carry detached anticlines, generally with overturned strata in the hangingwall.

The character of fold and thrust deformation changes from north to south within the study area, due to the change in the overall composition of the stratigraphic sequence. In the south, the presence of thick sections of competent Cambrian carbonate and quartzite results in a structural style dominated by imbricated thrust panels. The northward disappearance of these competent lithologies results in folding and penetrative cleavage becoming the dominant structural elements throughout the remaining part of the map area.

Although these previous statements are broadly correct, the apparent dominance of folding in the area north of Horneline Creek may be oversimplified and, may be a reflection of the relatively poor exposure and lack of marker horizons. The density of data points in this region is less than half of that to the south. As a result, a fairly conservative interpretation has been applied to the map and cross-sections. The structural interpretation favours upright to northeast-verging folding. The implications of this are that the extent of thrust faulting may be underestimated, particularly within the large expanse of monotonous Road River rocks south of Chee Mountain and within Kechika rocks north of Graveyard Lake.

Thrusts are by far the most dominant of the numerous faults recognized within the study area. Steep normal or reverse faults, although rarely documented south of Terminus Mountain, are delineated in several areas north of Horneline Creek, particularly along the western part of the map area. The Northern Rocky Mountain Trench strike-slip fault is the only example of this type recognized with certainty in the map area, but its significance, from a tectonic and geomorphological viewpoint, cannot be understated.

THRUST FAULTS

Thrust faults recognized within the map area are all northeasterly directed. Most of them trend northwesterly, with only the Chee Mountain and related thrust faults having a more northerly strike. The average length of these faults is approximately 15 kilometres with the longest being traceable for over 40 kilometres (Netson Creek thrust fault). The dip of the faults at surface, as observed in outcrop and inferred from cross-sections, is normally steep to very steep. The only exceptions to this are at the base of klippen of Cambrian carbonate southeast of Terminus Mountain and along Boya Hill where drill holes intersected a flat-lying thrust several hundred metres below surface (Moreton, 1984). This fault may connect southward across Boya Creek with a thrust along Chee Mountain, suggesting that it is also very shallow or that dip decreased to the north.

The relatively flat thrust carrying klippen of Cambrian carbonate above Silurian siltstone near Terminus Mountain

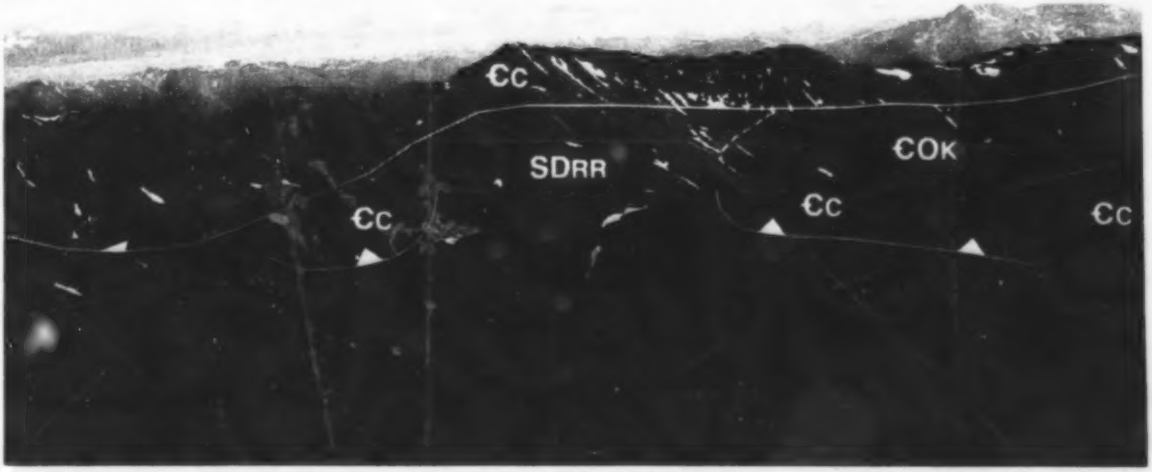


Photo 51. Looking west at klippe of Єc carbonate sitting above argillite and dolomitic siltstone of the Road River Group, about 5 kilometres southeast of Terminus Mountain. The Gataga Mountain thrust fault is approximately 1 kilometre to the west and carries overturned Єc carbonate in its hangingwall. The klippe, together with the underlying sediments, has been folded after being emplaced. Structural cross-sections suggest that the fault carrying the klippe is probably younger than the Gataga Mountain thrust.

(Photo 51) is probably not part of the Gataga Mountain thrust fault, because this would require the existence of a large nappe, which was later tightly folded. The most likely explanation is that the klippen are remnants of an earlier thrust panel or horse that formed ahead of the Gataga Mountain thrust.

Although many of the thrust faults are steep to near vertical, steep bedding dips are common in hangingwall strata, indicating the faults are parallel to sub-parallel to layering. This is particularly well displayed by cross-sections within the Cambrian carbonate sequence in the southern part of the map area. The present steep orientations of some strata and faults probably resulted when later compression imbricated and folded the stratigraphic sequence. This process may have led to the rotation of earlier structures and may explain the southwest vergence of folds and northeast dip of cleavage within Road River and Earn stratigraphy north of Split Top Mountain (*see* section B-B').

Major thrust faults in the map area carry Cambrian or uppermost Proterozoic strata in their immediate hangingwalls (Photos 52 and 53). Stratigraphic displacement on some of them, such as the Gataga Mountain and Split Top Mountain thrusts, ranges to more than 1000 metres. Absolute amounts of movement on different faults vary considerably and are based on interpretive cross-sections (A to G) and their extrapolation to depth. Movement on the Netson Creek, East Split Top and Gataga thrusts is probably in the order of 5 kilometres. Displacement on individual faults carrying slivers of Cc in the south (*see* western parts of sections B - B', C - C' and D - D') is unconstrained, but probably of similar order. The Chee Mountain thrust appears to have an absolute displacement of between 3 to 5 kilometres (section G - G' and extrapolation northward). The Brownie Mountain thrust has probably moved only 1.5 to 2 kilometres, and movements on many of the other faults in the map area are probably of this magnitude.

Displacement on major thrusts is substantially larger than on individual thrust faults found higher in the stratigraphy of each thrust sheet. Displacement on some of the larger faults must have been transferred into a series of smaller scale thrusts and associated folds in their footwalls. This is well displayed east of the Split Top Mountain thrust where Earn and Road River strata are repeated by small-scale folding and faulting (Photo 54). Thrusts within Earn and Road River rocks probably extended downward into the Kechika Group and this displacement must feed into the larger thrusts carrying Cambrian stratigraphy.

In the far southern part of the map area, large thrust panels of Cambrian carbonate commonly sit on Kechika or lower Road River shales, suggesting they are an important zone of detachment. This probably reflects the low structural competency of these lithologies and their location between more rigid siltstones of the Road River Group and the carbonates and quartzitic rocks of the Cambrian succession. This geometry also implies that the upper part of the Cambrian siliciclastic package also acted as a zone of weakness within the Cambrian carbonate belt, probably as a result of its relative incompetence with respect to overlying carbonates. North of the Cambrian carbonate shale-out, thrusts carrying Cambrian or Road River siliciclastics typically occur above incompetent lithologies of the Earn Group.

McClay *et al.* (1988), working adjacent to the southern end of the map area, delineated an early, westerly directed thrust fault which carries Cambrian siliciclastics and carbonates in its hangingwall. This structure can be traced northward to the Gataga River, extending into the southeastern part of our map area, and should involve the most easterly panel of carbonate. No such structure was observed, suggesting that this early structure has either lost all displacement or has veered to the east, outside the study area.

NORMAL FAULTS

Although no steep faults of normal displacement were directly observed in the field, they are inferred from map-pattern geometry. The only significant examples are north and east of Split Top Mountain. They are north-trending, west-side-down structures affecting Cambrian carbonates and siliciclastics in the footwall of the Netson Creek thrust, and Earn and Road River rocks in its hangingwall. Vertical displacement is in the order of several hundred metres.

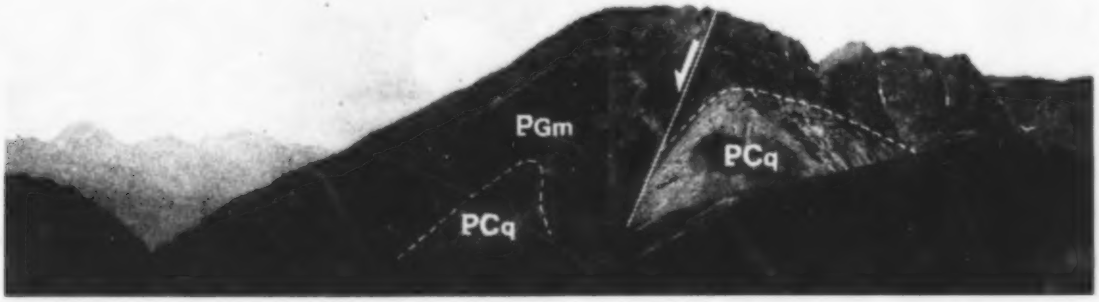


Photo 52. Looking north at Gataga Mountain. The structure of the Gataga Mountain anticline is particularly well outlined by the sediments of unit Pcq and a lighter coloured tuffaceous sediment horizon within the Gataga Volcanics (PGm). This structure must be cut by a late west-side-down normal fault, as shown here.

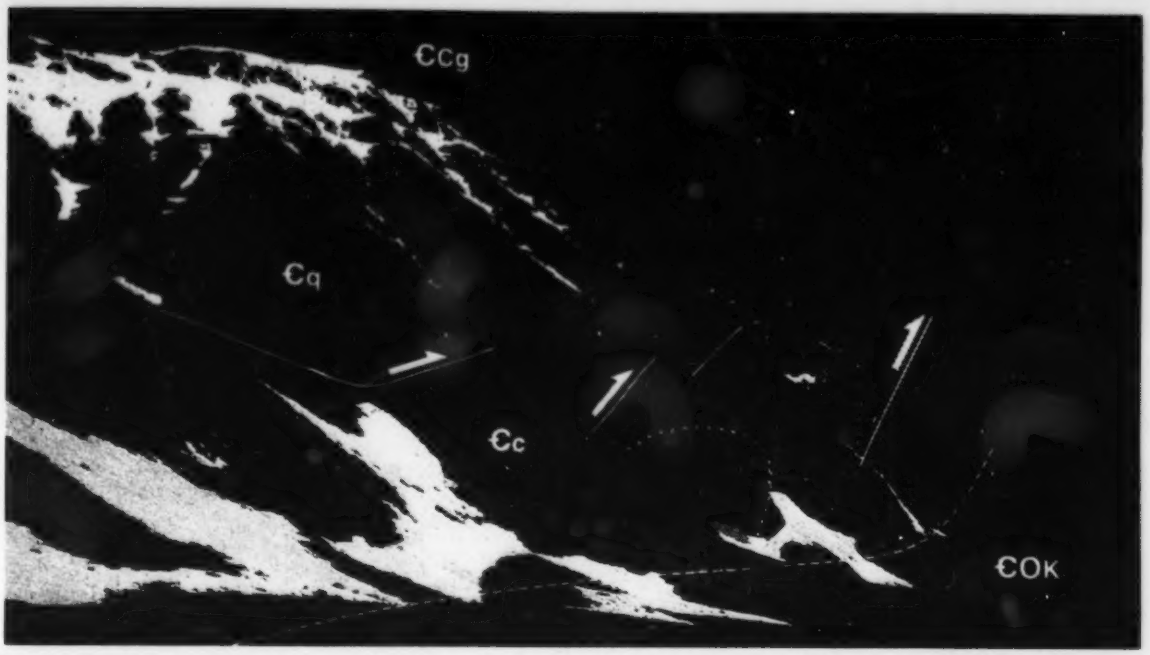


Photo 53. View to the north towards the east side of Brownie Mountain which shows Lower Cambrian quartzite of unit Єq and conglomerate of unit Єcg thrust over folded carbonate of Єc and calcareous argillite of the Kechika Group (ЄOK), both of which occur in the core of a northeasterly overturned syncline.

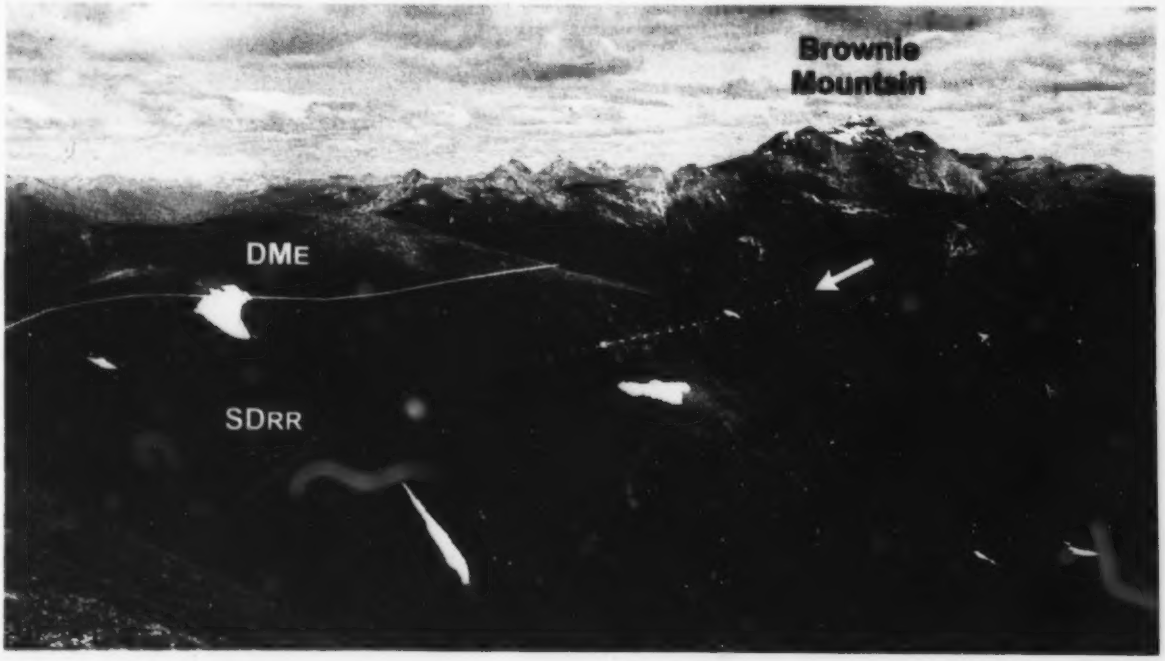


Photo 54. Looking north at a thrust panel of upper Road River dolomitic siltstones (SDRR), and argillites and slates of the Earn Group (DME). Bedding in the Road River siltstone sequence appears to be offset by a diagonal fault (thrust?) indicated by the arrow. This fault was not observed while traversing over the ridge due, in large part, to the monotonous nature of Road River lithologies.

Photo 55. Looking northwest along the Northern Rocky Mountain Trench from the western slopes of Gataga Mountain. The Kechika River can be seen in the valley bottom.

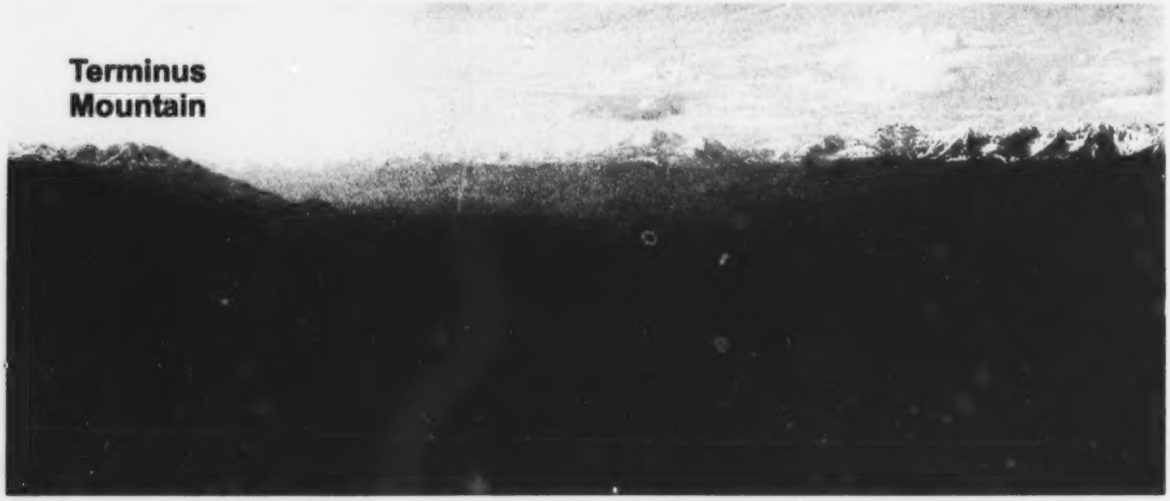


Photo 56. View to the south showing the northern termination of the Northern Rocky Mountain Trench. Terminus Mountain can be seen on the left of the photograph and the Cassiar Mountains in the background, across the trench. The observer is sitting on prominent hills within the Rabbit Plateau. Terminus Mountain is the last 'Rocky' Mountain along the northern end of this continental mountain belt. North of Terminus Mountain, the Northern Rocky Mountain Trench looses definition as it opens up into the Rabbit Plateau (as shown here) and is lost as a physiographic feature within the more northerly Liard Lowlands.

North of Horneline Creek normal faults are more significant in length and, to a certain extent, control the overall geometry of the map pattern. They trend northeasterly and are from 5 to 15 kilometres in length. Although not observed directly, the presence of these structures is supported by abrupt changes in geology across several prominent northeast-trending valleys, such as Horneline Lake, Graveyard Lake and several creeks to the north of here, Gemini Lakes and the northeast bend of the Kechika River. The faults are generally northwest-side-down and have displacements in the order of several hundred metres.

The fault along Graveyard Lake valley also delineates a boundary between two facies of the Kechika Group, which suggests it is a re-activated older, basin-controlling structure. These faults are roughly parallel to major faults Cecile *et al.* (1997) postulate influenced development of the western North American miogeocline during the early Paleozoic, particularly in this region, near the transition between the Kechika Trough and the Selwyn Basin.

NORTHERN ROCKY MOUNTAIN TRENCH FAULT

The Northern Rocky Mountain Trench fault takes its name from the great valley carved by the Kechika and Finlay rivers, and which, to the south, is now occupied by Williston Lake (Photos 55 and 56). This broad, well defined valley begins to lose expression north of Terminus Mountain and is essentially lost beyond the Red River, where it opens to the broad glacial-fluvial deposits of the Liard Plain. This northwest-trending structure is one of several major dextral faults of Late Mesozoic to Early Cenozoic age recognized along the length of the Canadian Cordillera (Gabrielse, 1985). It can be traced northwards into the Yukon where it links with the Tintina fault.

Only a few traverses near the headwaters of Calf and Mustela creeks crossed the inferred northward extension of the Northern Rocky Mountain Trench fault. In Calf Creek, sediments are brecciated and sheared and possibly mylonitized intrusive rocks outcrop along Mustela Creek. These exposures provide an approximate position for the fault, or its splays, in this region. Elsewhere on the Liard Plain, the position of the fault is virtually unconstrained and is very tentative. In the south, the location of the main fault is believed to be close to the lower, western slopes of the Kechika valley (H. Gabrielse, personal communication, 1996). A section of strongly sheared slates is exposed along the Turnagain River where it enters the trench (H. Gabrielse, personal communication, 1996). Strongly disrupted blue-black calcareous and noncalcareous slates and argillites exposed in scattered outcrops for several kilometres downstream from this location suggests there are splays off the main fault. These relationships suggest that fault motion is probably distributed over a wide zone as opposed to a discrete surface.

FOLDS AND CLEAVAGE

Many, if not all, of the thrust sheets in the map area are internally folded and have a penetrative or spaced cleavage in argillaceous lithologies. Folding played an equal or even greater role than thrust faulting in the overall structural development of the map area. Only one period of folding is apparent in most of the area. It is only in the Aeroplane Lake panel that the ubiquitous upright to northeast-verging folding and associated cleavage is seen to overprint an earlier phase of folding. This panel also exhibits the highest grade of metamorphism within the study area.

FOLDS

Fold styles in the study area reflect the composition of the affected rocks. On an outcrop scale, competent lithologies, such as carbonate and quartzite of units Cc and Cq, produce folds approaching parallel geometry, although they do have thickened hinge zones (Photos 57 and 58). These are probably Class 1C folds in the classification scheme developed by Ramsay (1967). They lack, or have a poorly developed, spaced cleavage. Thinly interlayered quartzite or quartz sandstone and slate commonly within unit Cs display chevron-like fold shapes.

Incompetent lithologies, including shale, slate and calcareous shale, contain a pervasive cleavage and exhibit thickened hinges and thinned limbs, approaching the geometry of Ramsay's Class 2 type folds (Photos 59 and 60). Similar-type folds are by far the most common in the map area, reflecting the dominance of shaly lithologies and the grade of metamorphism. The ubiquitous slaty cleavage, which is locally phyllitic or schistose, reflects the relatively elevated temperatures and increased ductility of these rocks, compared to those in eastern parts of the Rocky Mountains.

Megascopic folds, which are generally upright to northeast-verging, are recognized throughout the map area. Folds with southwest inclinations were observed on the west flank of Split Top Mountain and to the east, within the upper part of the Netson Creek thrust panel. They are less than 5 kilometres long and are open to closed, with wavelengths up to 1 kilometre.

Northeast-verging folds are open to tight in the south and generally become more open northward. These folds vary from a few to over 10 kilometres in length and have wavelengths up to several kilometres. Many could not be recognized directly in the field but were inferred from either bedding attitudes or outcrop distributions. One such fold begins a few kilometres west of Netson Lake, in rocks of the Kechika Group, and can be traced northward some 40 kilometres to the latitude of Scoop Lake. It is open and upright with a wavelength of 1 kilometre in the south and over 5 kilometres in the north.

The thick carbonate successions of unit Cc commonly delineate northeasterly overturned anticlines at the leading edges of thrust panels. Excellent examples of this are along the southwest side of Split Top Mountain and on the carbonate knoll east-northeast of Brownie Mountain (Photo 31). Apparently thick sections of Kechika and Ordovician shales in the south and southwestern part of the map area are probably the result of tectonic thickening in the cores of these larger scale folds, together with termination of thrust faults within this package.

Only a few large folds are exposed above tree line and clearly defined by contrasting lithologies or marker hori-

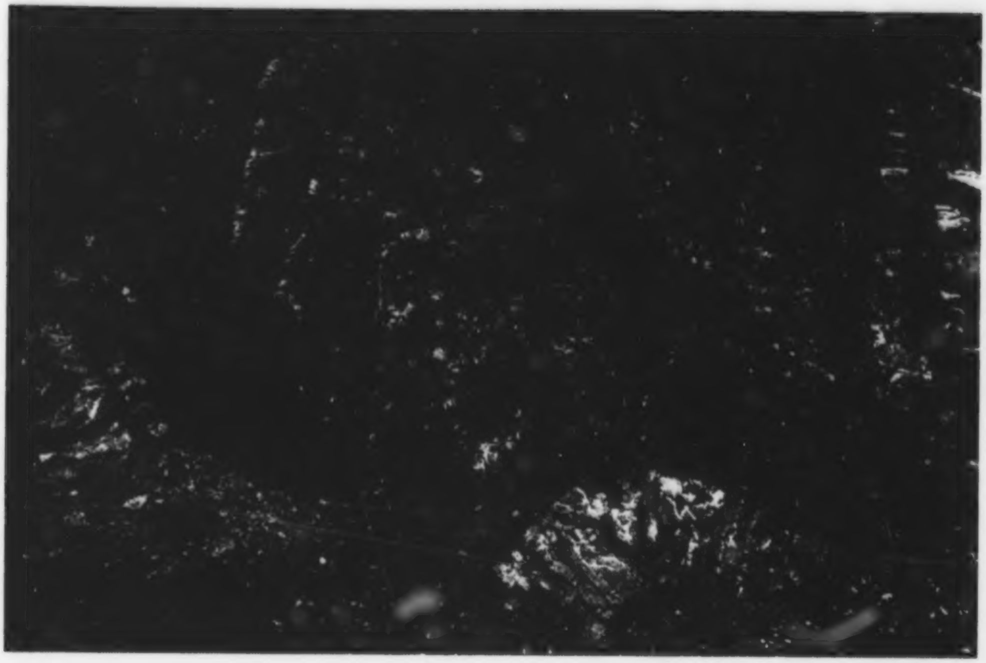


Photo 57. Parallel fold in thick quartzite layer in Cambrian siliciclastics exposed along the north shore of the lower Red River. Note that the less competent sediments above the anticline outlined by the quartzite layer have behaved more ductily, displaying a more similar fold style.

Photo 58. Open parallel folds developed in interlayered quartz sandstones, siltstones and slates of unit Cs approximately 5 kilometres south of Netson Lake.

Photo 59. Modified parallel fold outlined by calcareous argillite and argillaceous limestone in the upper part of the Road River Group(?). This outcrop is at the mouth of a west-flowing creek approximately 5 kilometres south of the confluence of the Red and Kechika rivers.

Photo 60. Similar-type folds developed in highly incompetent argillaceous lithologies of the Kechika Group. Note the well developed axial planar cleavage. The view is to the northwestand the outcrop is within the large area of Kechika Group rocks in the core of a northeasterly verging structure, east of Gataga Mountain.

zons such as unit Cc. These include the Brownie Mountain and Gataga Mountain anticlines (Photos 52 and 53). The Brownie Mountain anticline, as outlined by unit Cc, has a width of some 4 kilometres and a relatively short 10-kilometre length. Its northeast limb is overturned and cut by an easterly directed thrust carrying rocks of units Ccg and Cq. This thrust loses displacement northward and disappears in the core of the anticline. It plunges northwestward below an unusually broad belt of Kechika slates and limestones, which must represent the same anticline at this stratigraphic level. Structural cross-sections suggest that formation of this large fold cannot simply account for this anomalous thickness of Kechika strata (section D -D'). A blind thrust which repeats the Kechika Group and terminates within the core of this large anticline is a possible explanation. The northward continuation of this broad belt of Kechika rocks suggests this structure continues as far as Matulka Creek (section E - E').

The Gataga Mountain anticline begins several kilometres south of Gataga Mountain and ends at Terminus Mountain, some 20 kilometres to the northwest. This fold is similar in size and configuration to the adjacent Brownie Mountain anticline. It is delineated by Cambrian and Precambrian clastics, carbonates and volcanics. This large, northeast-verging fold is open to closed and its eastern limb is overturned (Photo 52). Superficially, this structure appears to be related to the underlying Gataga thrust fault, but the fault abruptly cuts off the fold, which suggests otherwise. The central part of the fold is cut by a smaller thrust(?) fault south of Matulka Creek and is clearly visible disrupting maroon beds of unit Ccgm along the top of the ridge.

Folds generally become more open and upright north of Terminus Mountain (sections F - F' and G - G'). Recognition of thrust faults in this region is hampered by the monotonous nature of the lithologies. Thus the broad region of open folding within the Road River Group north of Terminus Mountain may actually be more complicated than depicted, with both thrusts faults and folds giving a structural style like that of the broad region of Kechika rocks between the Gataga and Kechika rivers (section A - A').

Early Folding?

Locally, calcareous and noncalcareous rocks of the Aeroplane Lake panel exhibit layer-parallel to sub-layer-parallel tight to isoclinal folds (Photos 61 and 14). They are best developed in calcareous rocks along the east side of unit PPal and are also associated with higher grade metamorphism. Many of these folds have rootless limbs

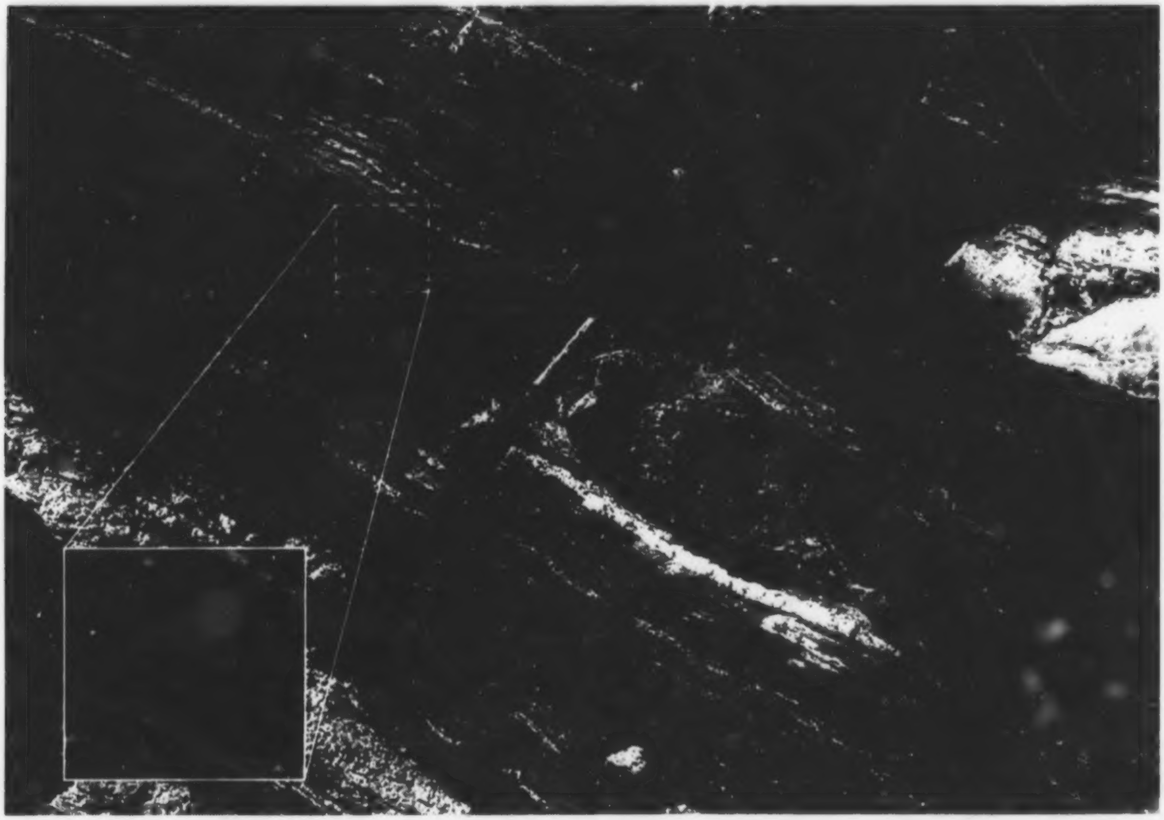


Photo 61. Layer-parallel fabric in calcareous lithologies of unit PPal (Aeroplane Lake panel) seen 'wrapping around' a more competent lens of carbonate. Small isoclinal folds (inset) are associated with this fabric. This early deformation is cut by latter upright fold structures (*see* Photo 14). This outcrop is on the east side of the ridge approximately 10 kilometres northeast of Twin Island Lake.

and the host lithology may exhibit a strong layer-parallel ductile fabric, as seen in unit PPal, suggesting intense shearing. Folds and the layer-parallel fabric were affected by the dominant upright folding which crenulates the earlier fabric.

The significance of this folding is not fully understood. It suggests the presence of an earlier phase of deformation linked to a pulse of increased metamorphism, but textural relationships suggest that peak metamorphism occurred during crenulation folding. The higher metamorphic grade still suggests this region was subjected to higher overall temperatures than other parts of the map area, which resulted in increased ductility. These early structures may simply have formed during the initial phases of a protracted period of thrusting within the Rocky Mountain fold and thrust belt. It is known that shortening within this structural province occurred over a period spanning the Cretaceous to earliest Tertiary. It can be demonstrated, from the character of the clastic wedge shed eastward from the tectonically thickened crust, that deformation occurred in pulses. Thus, layer-parallel folding within the Aeroplane Lake panel may have resulted from early and intense movement along a significant fault, or series of faults, resulting in transposition of bedding and cleavage in these zones. Outside these localized strain zones, resulting structures were more upright and had orientations typical of the Rocky Mountain fold and thrust belt. Subsequent shortening would have refolded this layer-parallel fabric, whereas away from these zones, upright structures would be amplified.

CLEAVAGE

A pervasive, slaty cleavage is present within argillaceous rocks throughout the map area (Photo 62). Cleavage is rare in clean quartzite and carbonate, but when present it is a widely spaced fracture cleavage. Thinly to moderately interlayered quartzite and slate commonly display classic refractive cleavage-bedding relationships. A pressure-solution cleavage is sometimes seen in argillaceous limestones. Analysis reveals that cleavage generally displayed a northwest-striking and southwest-dipping attitude. Northeast-dipping cleavage is observed in areas where associated fold structures are southwest verging; such as in the Split Top Mountain and Aeroplane Lake areas.

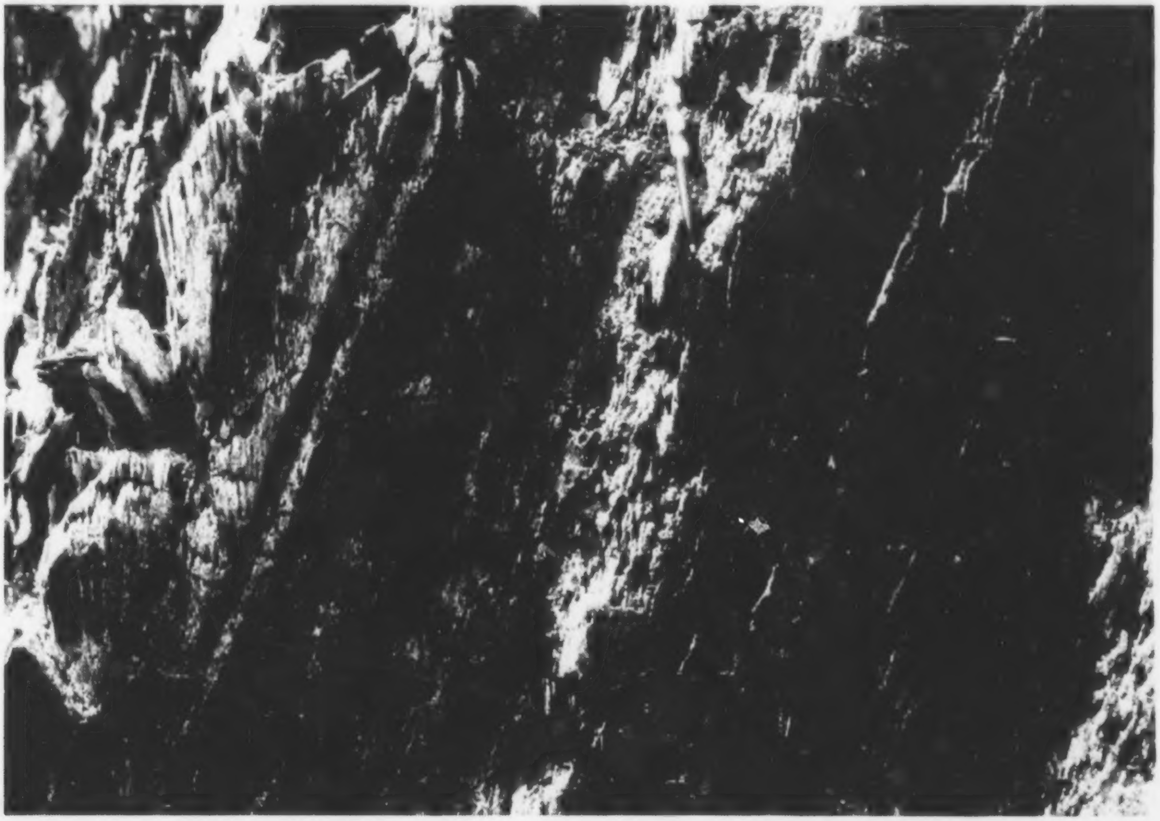


Photo 62. Well developed slaty cleavage in orange-weathering dolomitic slates of the Kechika Group, about 3 kilometres northwest of Bluff Creek. Due to the argillaceous nature of most lithologies, cleavage is the dominant structure at the outcrop level. It may be either penetrative, as seen here, or a more spaced cleavage in more competent sandstones, or a dissolution cleavage in carbonate-rich rocks. Some lithologies, such as clean carbonate of unit Єc or quartzite of unit Єq lack cleavage.

A crenulation cleavage is present within higher grade schists and phyllites of the Aeroplane Lake panel. It generally strikes north-northwest to north-northeast, and dips gently to steeply east (Figure 17). Crenulated phyllites and schists are associated with polydeformed carbonate rocks (*see* section on Folding). Lithologies in parts of the Aeroplane Lake panel contain a strong, layer-parallel fabric with associated tight folds and these are overprinted by broader, upright fold structures with axial planes parallel to the crenulations.

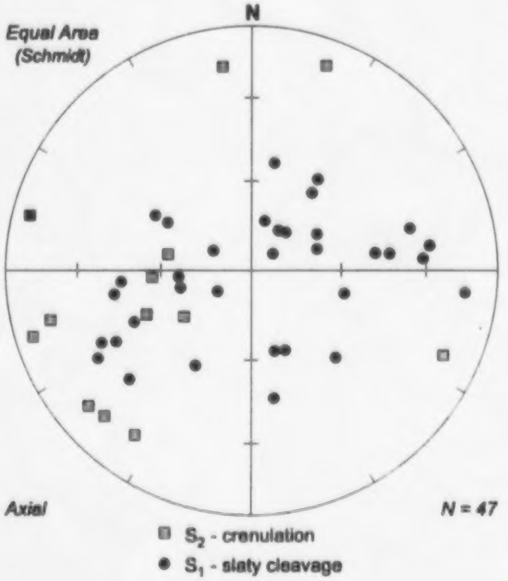


Figure 17. Poles to slaty (S_1) and crenulation cleavage (S_2) plotted on an equal area (Schmidt) stereonet. Data points are from the strata of the Aeroplane Lake panel.

CHAPTER 4 METAMORPHISM

Low-grade metamorphic conditions, as defined by Winkler (1979), characterize the study area. Pelitic rocks contain white mica (illite or phengite), chlorite, quartz, calcite and dolomite. Metamorphic mineral assemblages in mafic volcanics of Proterozoic and Cambrian age consist of chlorite, calcite, albite(?) ± epidote ± white mica ± pumpellyite ± stilpnomelane. The lack of actinolite again suggests very low grade metamorphic conditions.

Slightly higher metamorphic grades are displayed by rocks of the Aeroplane Lake panel and in the area along Boya Hill. Elevated conditions within most of the Aeroplane Lake panel are a regional phenomenon whereas parts of this sequence in the Boya Hill area display textures resulting from contact metamorphism (Figure 18). Argillaceous limestones of unit PPal are coarsely recrystallized along the top of the ridge east of Twin Island Lake. In hand sample, some of these rocks display a strong layer-parallel fabric which may be crenulated (Photo 63). Preferential alignment of phlogopite and other minerals in these rocks suggests they formed during dynamothermal regional metamorphism. Locally, the recrystallized nature of the fabric elements suggests contact metamorphism. Petrographic examination shows that strain associated with crenulations and the earlier layer-parallel fabric has been annealed (Photo 64). Removal of this strain and the coarse recrystallized grain size are only observed within parts of the Aeroplane Lake panel, suggesting the presence of a buried intrusion. This inference is supported by the occurrence of felsic dikes cutting unit PPac just to the south of the area and Paleozoic rocks to the northeast.

Cambrian and Late Proterozoic rocks on Boya Hill are variably hornfelsed around felsic intrusions of late Early Cretaceous age. Moreton (1984) describes a metamorphic aureole around these intrusions comprising purplish brown biotite and quartz-rich rocks. There is no mineral zonation evident within the aureole, but several hornfels mineral assemblages, as defined by Turner (1981), are recognized. In pelitic rocks these range from albite-epidote to hornblende hornfels, with local occurrences of corundum and andalusite-bearing pyroxene hornfels adjacent to larger intrusions. Hornfels assemblages in carbonate rocks consists of clinopyroxene-quartz-calcite±tremolite±potassium feldspar. Locally, carbonate rocks are skarned and mineral assemblages in the most intensely affected areas include wollastonite, grossular garnet and vesuvianite. A more detailed description and distribution of these assemblages is provided by Moreton (1984).

Elsewhere within the Aeroplane Lake panel, regional metamorphism of pelitic rocks produced phyllites and schists, which locally contain porphyroblasts of chloritoid, carbonate and biotite. Calcareous rocks of unit PPal contain calcite, quartz, muscovite, phlogopite and local talc. The presence of talc is inferred from the 'greasy' nature of some samples in the field but is not confirmed by petrographic ob-

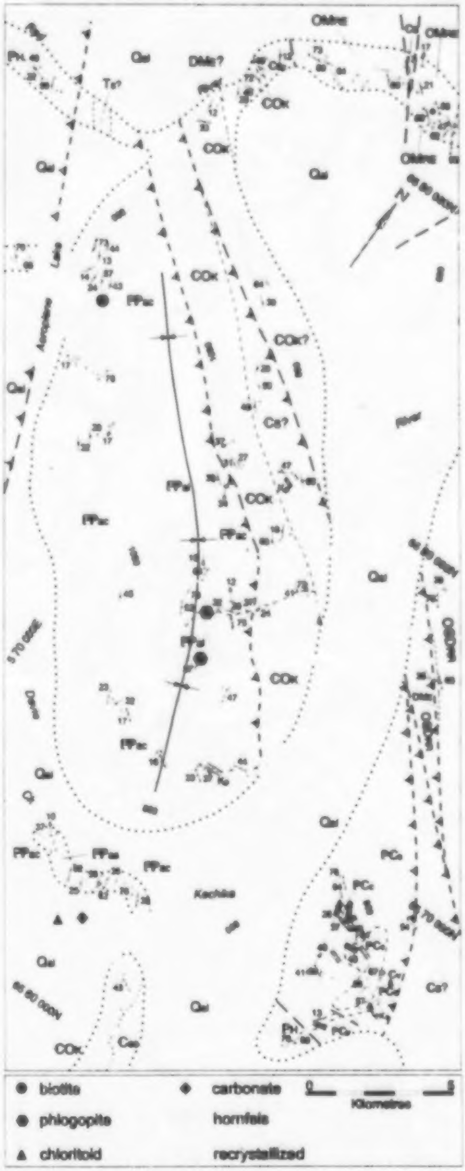


Figure 18. Simplified geological map of the area between Boya Hill and the Red River, showing areas of hornfelsing and recrystallization in Paleozoic and/or Proterozoic sediments. Although intrusive sills, dikes and small stocks are present in the Boya Hill area, the large area of hornfelsing and associated skarn suggests the presence of a larger intrusion at depth. Similarly, a large, poorly defined area of recrystallized rocks within the Aeroplane Lake panel infers the presence a large, buried intrusion. The only evidence of intrusive activity is in the form of several small felsic dikes (Kp) in the area. Unit labels are the same as those on the accompanying geoscience maps.

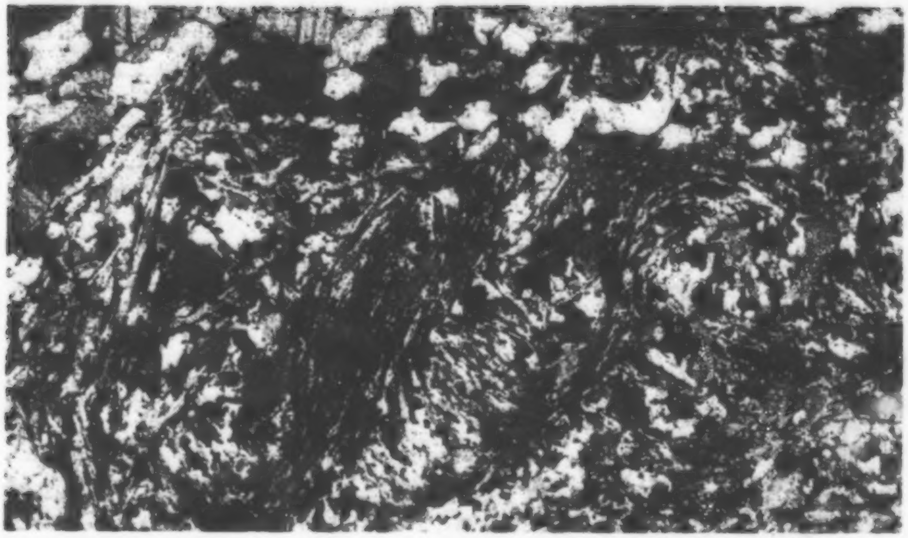


Photo 63. Photomicrograph of crenulation in slates and limestones of unit PPal. Long axis of photomicrograph is 6 millimetres.

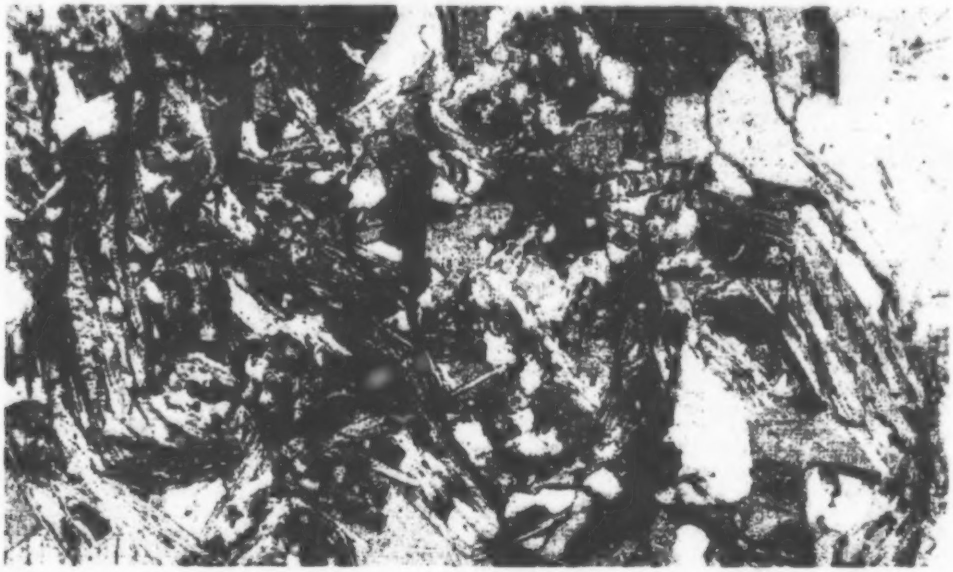


Photo 64. Photomicrograph showing annealed texture in crenulated slates and calcareous rocks of unit PPal. Long axis of photomicrograph is 2 millimetres.

servation. The presence of chloritoid and biotite porphyroblasts, together with the mineral assemblages in carbonate rocks, indicate the beginning of low-grade metamorphic conditions (*i.e.* greenschist grade; Winkler, 1979). Mapping of a biotite mineral isograd in pelitic rocks is not possible due to its sporadic occurrence.

Textural relationships between cleavage generations and porphyroblasts allow interpretation of the relative timing of deformation and metamorphism (Photos 65 to 69). This procedure assumes that maximum porphyroblast growth represents peak metamorphic conditions.

Crenulated calcareous phyllite at the mouth of Davie Creek contains carbonate porphyroblasts with apparently straight inclusion trails (Photo 65). Furthermore, the layer-parallel fabric in surrounding phyllite is not deflected or flattened around the carbonate crystals. Poorly developed crenulations in enclosing phyllite are deflected by these porphyroblasts. Tiny randomly oriented chloritoid needles are present in the groundmass (Photo 66). The rela-

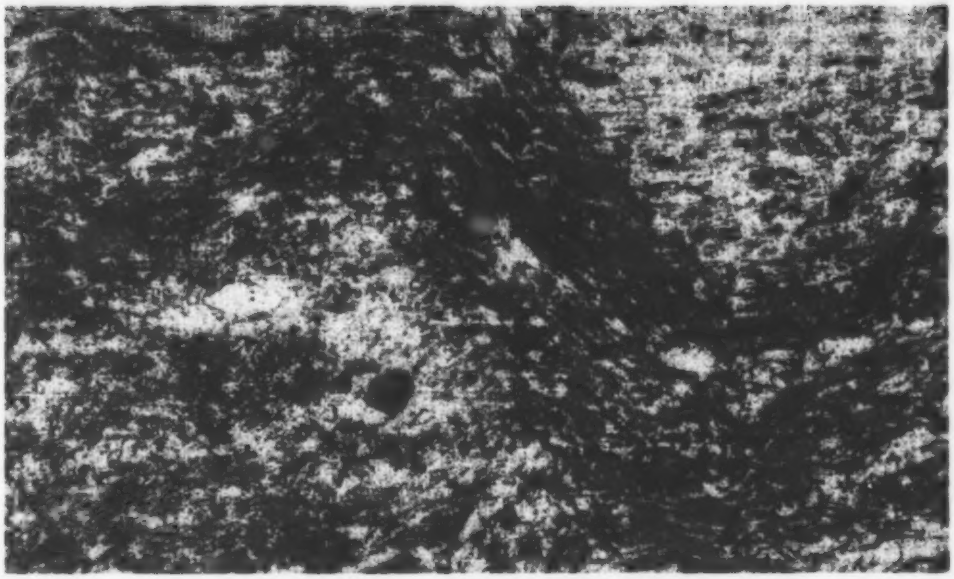


Photo 65. Photomicrograph of crenulated calcareous phyllite in unit PPal, containing carbonate porphyroblasts. Note the straight inclusion trails displayed by the porphyroblasts. Long axis of photomicrograph is 2 millimetres.

Photo 66. Photomicrograph of randomly oriented needles of chloritoid in phyllites of unit PPal. Long axis of photomicrograph is 2 millimetres.

tionship between chloritoid growth and crenulation formation is equivocal due to the former's small crystal size and the openness of the crenulations.

Crenulated biotite-muscovite-carbonate-quartz schist crops out just east of Aeroplane Lake. Here, biotite porphyroblasts, up to 1 millimetre long, are typically preferentially aligned at high angles to the prominent layer-parallel foliation, although many are also parallel or subparallel to this fabric (Photo 67). Most of the high-angle biotite porphyroblasts appear to have grown parallel to the crenulation, although some of the larger crystals appear to be kinked in the hinge zones of some of the tighter crenulations (Photos 68 and 69).

These relationships suggest a relatively simple timing relationship which is summarized in Figure 19. The layer-parallel fabric represents the earliest structure affecting these rocks and predates peak metamorphism, as shown by the absence of deflection around porphyroblasts and by

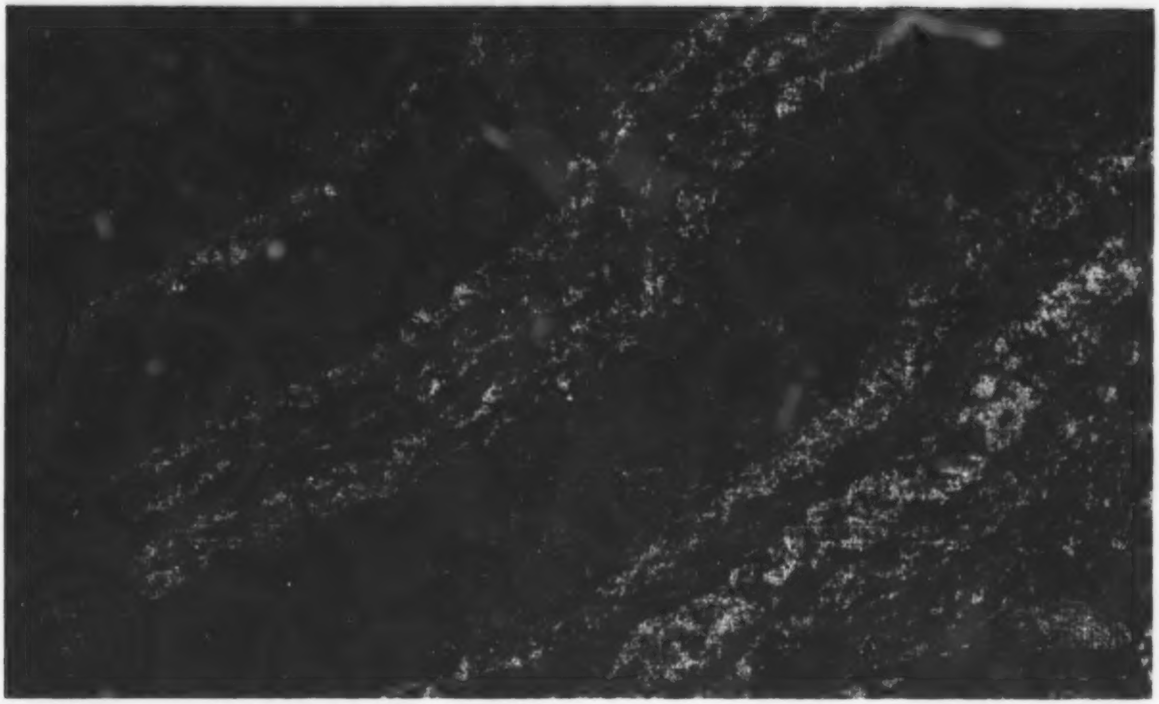


Photo 67. Photomicrograph of phyllites in unit PPal showing long axes of biotite porphyroblasts aligned at an angle to the main crenulation axial plane. Long axis of photomicrograph is 6 millimetres.

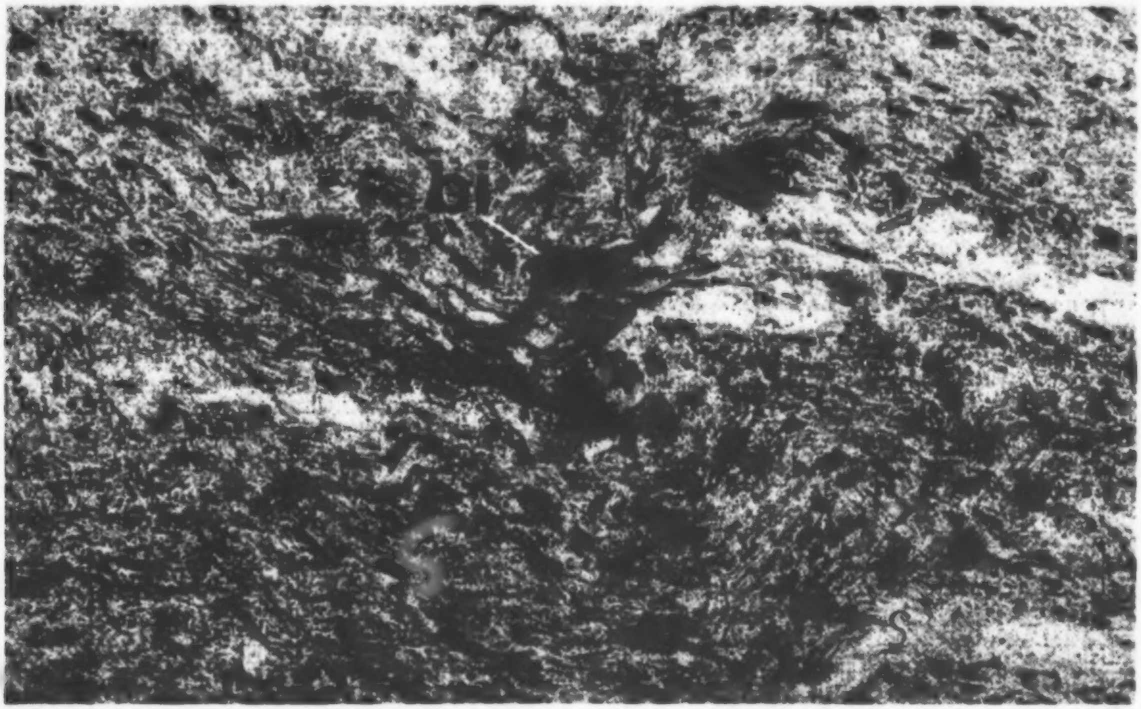


Photo 68. Photomicrograph showing kinked biotite porphyroblast (bi) in core of crenulation in phyllites of unit PPal. Long axis of photomicrograph is 2 millimetres.

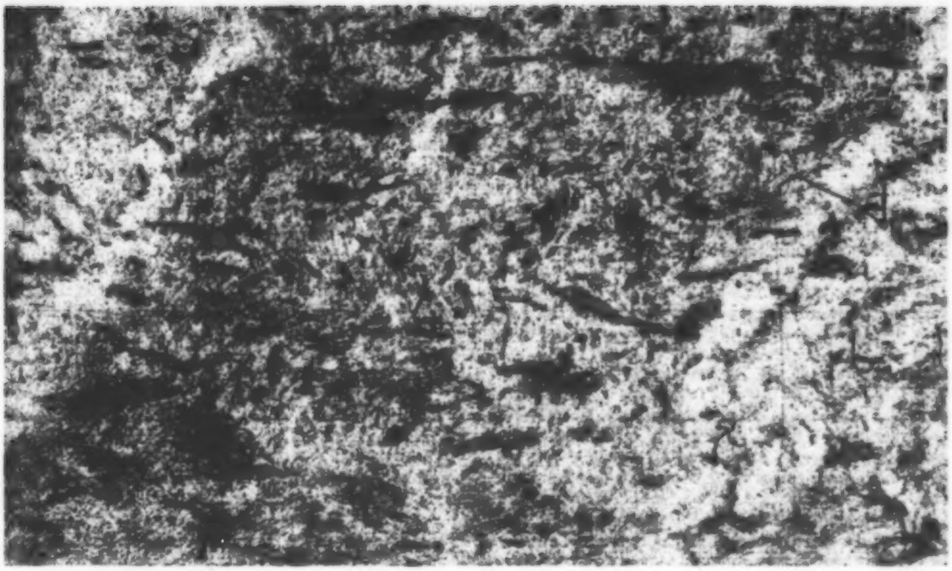


Photo 69. Photomicrograph of PPal phyllites showing long axes of biotite porphyroblasts aligned parallel or subparallel to crenulation axial planes. Long axis of photomicrograph is 2 millimetres.

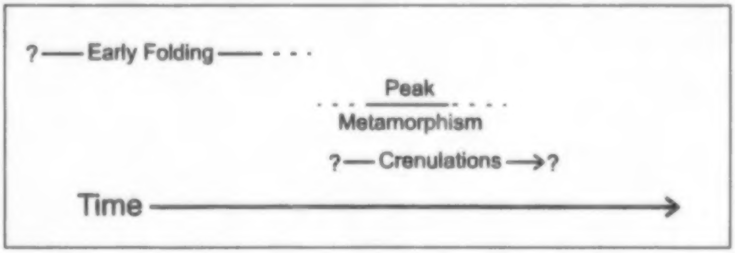


Figure 19. Relative timing of deformation and regional metamorphism as deduced from interaction between porphyroblast growth and folding as seen in the Aeroplane Lake panel.

the nonalignment of the porphyroblasts within this foliation. This fabric was later refolded and crenulated in conjunction with peak metamorphic conditions, as demonstrated by the growth of biotite crystals parallel or subparallel to the axial planes of the crenulations. This deformation appears to have outlasted metamorphism, as indicated by kinked mica porphyroblasts in crenulation hinges. The significance of these relationships to the regional structural evolution of these rocks is discussed in the chapter on Structure, at the end of the section on Folding.

CHAPTER 5 ECONOMIC GEOLOGY

The early to middle Paleozoic Kechika and Selwyn basins, in British Columbia and Yukon Territory, respectively, together define a metallogenic province containing economically significant sedimentary exhalative (sedex) Pb-Zn-Ba deposits (Figure 1). These occur at several stratigraphic horizons within the basins and include both the Cambro-Ordovician Anvil mineral district and the Silurian Howards Pass deposits. Sulphide and barite occurrences of probable sedimentary exhalative origin also occur in the Ordovician (MacIntyre, 1992; 1998). The succeeding eastward-prograding Upper Devonian clastics of the Earn Group represent an equally important sedex metallotect containing important deposits in the Macmillan Pass and Gataga areas (*e.g.* Tom, Jason, Driftpile Creek, Cirque, Akie; Abbott *et al.*, 1986; Figure 1).

Mapping over the course of the project located numerous stratiform barite occurrences, nearly all of them in the Devono-Mississippian Earn Group (Figures 2 and 3; Tables 4 and 5). Barite mineralization was also noted in Lower Silurian and Ordovician shales of the Road River Group and basal rocks of the Kechika Group. Other significant, and related, mineral occurrences include a zone of lead-rich veinlets in Earn(?) rocks, and a previously known zinc and barite-rich crosscutting breccia in chert and limestone of the upper Road River Group. Anomalous Ni-Zn values in some areas underlain by Earn rocks suggest the possible presence of stratiform nickel-zinc-platinum group element (PGE) deposits similar to those in the Selwyn Basin (Hulbert *et al.*, 1992; Carne and Parry, 1990; Carne 1991).

Elevated levels of barium, zinc and other elements in lake sediments near Kitza Creek facies lithologies (Cook *et al.*, 1997), together with minor occurrences of sulphide-bearing veins and stratabound sulphide mineralization, suggest these rocks deserve greater attention and may host significant sedex mineralization.

The tungsten-molybdenum stockwork-skarn prospect on Boya Hill is the only known intrusion-related deposit within the map area (Figure 3; Table 4b). The age and character of related igneous rocks are similar to the widespread middle Cretaceous Selwyn Plutonic Suite of the northern Cordillera, which is associated with several significant tungsten skarn and molybdenum-tungsten stockwork-skarn deposits (*e.g.*, MacTung, CanTung; Gordey and Anderson, 1993).

Minor mineral occurrences in the map area include: epigenetic galena in slate of unit Cc; malachite staining in maroon and green siltstones of unit CPs; chalcopyrite and tetrahedrite(?)-bearing quartz veins in carbonate rocks of unit Cc and rare veins of barite and tetrahedrite(?) in Earn rocks (Figures 2 and 3; Tables 4 and 5).

SEDIMENTARY EXHALATIVE (SEDEX) MINERALIZATION

In Canada, sedimentary exhalative (sedex) deposits are an important source of zinc, lead and silver. Over the last decade they accounted for 15 and 20 per cent of zinc and lead production, respectively (Lydon, 1996). This has been obtained primarily from the Middle Proterozoic Sullivan deposit and the Cambrian occurrences in the Anvil camp. Furthermore, significant reserves of sedex Zn-Pb±Ag in Cambrian, Lower Silurian and Upper Devonian strata, in addition to the Earn Group, mark the Selwyn and Kechika basins as important metallotects within the Canadian Cordillera. Considering the economic significance of these deposits, a brief summary describing their general characteristics and a genetic model is warranted. The following discussion is concerned primarily with sedex deposits within the Selwyn and Kechika basins and draws heavily from the work of current and earlier workers who studied this deposit type, including (and references cited within): Carne and Cathro (1982), MacIntyre (1991; 1992; 1998), Lydon (1996), Morganti (1981), Pigage (1986), Goodfellow and Jonasson (1986), Bailes *et al.* (1986), Jennings and Jilson (1986), McClay and Bidwell (1986), Paradis *et al.* (1998), Goodfellow *et al.* (1993) and Large (1983).

The term "sedimentary exhalative" (sedex) deposit was first proposed by Morganti (1977) for the Howards Pass occurrences and later 'popularized' by Carne and Cathro (1982) in describing shale-hosted stratiform Zn-Pb-Ag deposits within the Selwyn and Kechika basins. As the name implies, these deposits are believed to have formed in a sedimentary sequence by the exhalation of hot, metalliferous brines along fissures on the seafloor, resulting in precipitation of ore and gangue minerals. In addition, neither intrusive nor volcanic activity is generally associated with these occurrences and, where present, is only of very limited extent.

The principal ore minerals are sphalerite and galena (containing silver) which are found with varying amounts of pyrite, barite, pyrrhotite and clastic sedimentary gangue minerals. Copper is rarely present and only in very minor amounts. Typical grades and tonnages for Selwyn and Kechika basin deposits are listed in Table 6. The deposits are lensoidal and, where it can be recognized, sit above a mineralized stockwork system believed to represent the underground conduits that fed metal-bearing fluids to surface vents.

Fluid-inclusion data indicate that these are low-temperature systems (150 to 300°C). These low temperatures, together with the lack of volcanic rocks in the stratigraphic sequence, account for the general absence of copper ores. If present, copper is in the form of chalcopyrite and is found in the underlying vein stockwork or directly above, in the adjacent massive orebody. Ore and non-ore minerals are vertically and horizontally zoned within the

TABLE 4A

MINERALIZED SAMPLE SITES AND MINERAL OCCURRENCES FOUND WITHIN THE SOUTHERN MAP AREA MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 2

MAP NUMBER	MINFILE Number and Name[1]	FIELD NUMBER	EASTING	NORTHING	UNIT	COMMODITY	DESCRIPTION
1	**094L 022**	FFE95-5-13-2	622800	6499470	Pcq	Pb	5 to 10-cm zone of patchy galena in sheared, fractured, silicified slates.
2	**094L 028**	FFE95-18-13	615225	6506050	CPs	Cu	Malachite-bearing, maroon and pale green siltstone.
3	**094L 028**	JN95-7-4	610250	6514250	Cs and Cc	Cu	Sparse chalcopyrite and malachite in breccia near contact between units Cs and Cc
4	**094L 006 Black Wednesday**	FFE94-10-19-2	637390	6492250	Cc	Cu	Malachite and chalcopyrite-bearing quartz veing in Cc limestones.
5		FFE94-3-12-2	643293	6489000	COk	Ba	Green slate with 1-3 cm thick horizon containing authigenic barite crystals.
6		FFE94-30-6	637961	6499440	COk	Ba	Calcareous, grey slate with 1cm thick horizon containing authigenic barite crystals.
7		JN94-5-7	644154	6487465	COk	Ba	Green slate with 1-3 cm thick horizon containing authegenic barite crystals.
8		CRE95-23-3	618570	6512275	COKR	Ba	Beds of dolomitic siltstone with authigenic barite crystals, in black slates.
9	**094L 016 Smoke**	FFE95-43-7-3A	610070	6526340	SDRR	Zn, Ba	Gossenous, 3-m wide sphalerite-barite calcareous breccia zone in chert-limestone; top of unit SDRR.
10	**094L 027**	FFe94-18-8	632290	6497800	DME	Ba	Baritic shale.
11	094L 015 Solo	FFe94-24-13	632515	6501560	DME	Fe, Zn	Ferricrete.
12	094L 015 Solo	FFe94-25-6	633765	6501750	DME	Ba	Baritic shale.
13	094L 027	FFe94-27-15	631745	6498860	DME	Ba	Baritic shale.
14	**094L 026**	FFE94-29-13	634700	6500025	DME	Cu, Ba	Copper-barite-quartz vein.
15	094L 018 Bluff Creek	FFe94-38-3-1	637640	6493850	DME	Ni, Zn, Fe	Ferricrete.
16	**094L 021**	CRE95-9-9	627800	6501915	DME	Ba	0.5 m thick, bedded, baritic siltstone, finely disseminated or in rosettes up to 1 cm.
17	094L 020	JN95-3-7	631000	6503500	DME	Ba	Several 10 to 30 cm thick barite beds in siltstone-mudstone.
18	094L 020	JN95-3-8	530785	6503635	DME	Ba	Laminated barite beds in siltstone-mudstone.
19	**094L 020**	JN95-4-1	630460	6503825	DME	Ba	Laminated to massive grey barite, and baritic lenses in mudstone, alternating over 2 m.
20	094L 020	JN95-4-2	630215	6504000	DME	Ba	As above, strongly folded
21	094L 020	JN95-4-3	629925	6504125	DME	Ba	Several layers of barite, up to 2 m thick, in laminated mudstone and slate.
22	094L 020	CRE95-11-6	628600	6504575	DME	Ba	Slate and siltstone with thin bed containing small barite crystals.
23	**094L 023**	FFE95-12-2	625300	6506310	DME	Ba	0.5 m thick bed of calcareous barite, in limestone and cherty argillite.
24	**094L 024 Broken Bit Barite**	FFE95-13-1-1,2	624950	6507125	DME	Ba	'Broken Bit barite' kill zone: regolithic granular 'sand' of calcareous barite.
25	**094L 025**	FFE95-27-7	622300	6509325	DME	Pb, Ba	Galena-bearing quartz in highly fractured slate, siltstone; baritic limestone nearby.
26	094L 025	FFE95-27-4	622575	6509900	DME	Ba	1 to 5 cm thick beds of baritic limestone; slate and siltstone with barite crystals and pyrite.
27	094L 019 Mat	FFE95-22-6	626690	6510165	DME	Ba	Grey, calcareous barite in beds 1 to 20 cm thick, over 2 m.
28	094L 019 Mat	FFE95-22-8 to 12	626080	6510860	DME	Ba	Calcareous barite beds, up to 2 m thick, and siltstone with 1 to 5 cm barite nodules; locally rusty.
29	**094L 029**	FFE95-23-7	623460	6512210	DME	Ba	Several horizons, 3 to 10 cm thick, with barite rosettes and crystals, and disseminated pyrite in siltstone and slate.
30	094L 029	JN95-8-6	622485	6512600	DME	Ba	Small chips of baritic mudstone in black, bedded radiolarian chert.
31	**094L 031**	CRE95-24-7	623100	6514000	DME	Ba	2 m thick, thinly bedded, black calcareous barite with small chert nodules; in siltstone and chert.
32		CRE95-26-3-3	624250	6515650	OSRR	Fe	Pyritic slate to siltstone, rusty weathering; some coarse (2 cm) pyrite nodules, probably near base of unit.
33	094L **032**	JN95-6-1	621375	6517100	DME	Ba	Coarse-grained barite bed, 2 to 3 cm thick, in black siliceous mudstone and chert.
34	**094L 033**	JN95-14-1	619375	6515865	DME	Ba	Calcareous barite with small chert nodules, interbedded with chert and slate.
35	094L 033	CA95-2-6	618600	6517550	DME	Ba	Weakly baritic limestone, with small black chert nodules, in cherty siltstone
36	**094L 034**	JN95-10-10	614950	6518150	DME	Ba	Calcareous barite bed, 1.5 m thick, with small black chert nodules, in chert and siltstone
37	**094L 035**	FFE95-29-11	612245	6517120	DME	Ba	Dark grey, fetid, baritic limestone with chert nodules, 0.5 m thick, in argillite and slate of unit
38		CA95-1-1	611000	6517400	DME	Ba	Baritic chert and limestone.
39		CA95-1-3	610050	6517750	DME	Ba	Bed of baritic chert or argillite.
40	**094L 036**	FFE95-47-8	609265	6519200	DME	Ba	Dark grey, baritic limestone with chert nodules, up to 1.5 m thick, in slates and argillites.
41	**094L 037**	CRE95-38-1-2	614750	6521900	DME	Ba	Black, fetid, calcareous barite, over 1 m thick, in slates
42	**094L 038 Chief**	FFE95-46-11/12	615600	6524365	DME	Ba	Massive to flaggy, 2 m thick bed of crystalline calcareous barite, in argillites of unit DME
43	**094L 039**	FFE95-46-1	616000	6525775	DME	Ba	Fetid, bedded, calcareous barite, 1.5 m thick, in dark grey argillites.
44	094L 039	JN95-13A-12	615175	6527225	DME	Fe	Rusty, siliceous slate with disseminated pyrite.
45	**094L 040**	JN95-13-6	613400	6526275	DME	Ba	Thin, massive to laminated baritic siltstone, in pyritic carbonaceous mudstone and slate.
46	**094L 041 Horn 5**	CRE95-44-3	610260	6527260	OSRR	Ba	Baritic limestone lenses, 0.5 to 1 m thick, with barite clasts and rosettes, in siltstone and slate.
47	**094L 042**	FFE95-41-3	607700	6524525	OSRR	Ba	Argillite layer, 0.5 m thick, with up to 30% barite rosettes; also baritic limestone lenses.

[1] Bold highlight indicates that the sample location represents the position of the occurrence as recorded in the Minfile data base. Un-highlighted samples are associated mineral occurrences. Mineral occurrences without Minfile numbers do not qualify for inclusion in the Minfile database

TABLE 4B

MINERALIZED SAMPLE SITES AND MINERAL OCCURRENCES FOUND WITHIN THE NORTHERN MAP AREA. MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 3

MAP NUMBER	MINFILE NUMBER	FIELD NUMBER	EASTING	NORTHING	UNIT	COMMODITY	DESCRIPTION
2		FFE96-19-4	569642	6592737	ODrk	Fe	Layer-parallel, pyrite-rich horizons, 0.5 to 2 cm thick, and traceable for up to 5 m within thin to thickly interlayered, dark grey to black calcareous siltstone to argillaceous siltstone and dark grey, very finely recrystallized silty limestone.
3	094M 020 Red	FFE96-19-4b	569642	6592737	ODrk	Zn	Smithsonite-bearing calcite vein approximately 30 cm thick within lithologies at locality 1.
4		FFE96-25-11	599207	6541353	ODrk	Fe	Layer-parallel, pyrite-rich horizons, 0.1 to 2 cm thick, within dark grey to grey slate or silty slate to quartz wacke.
6		CRE96-17-3	568413	6604785	ODrk	Ba	Grey to dark grey or black, blocky to platy calcareous and baritic siltstone to silty limestone with thin calcareous sandstone horizons.
7	094M 018 Kitza	CRE96-17-6-1	570319	6605220	ODrk	Zn, Cu, Pb?	Sphalerite, malachite and galena?-bearing quartz-carbonate veins and veinlets within grey to dark bluish grey, massive to blocky, fine-grained, fetid limestone.
9		CRE96-25-3	602000	6541146	ODrk or DME	Fe	Dark blue grey to blue-black, argillite with lenses of pyritic siltstone.
10	094M 023 Kechika River Barite	JN96-11-3	578274	6585350	DME	Ba, Fe	Thin to moderately interlayered or massive barite, with thin pyrite laminae, and grey to light grey slate.
	104P 072 Roman		523087	6651122	DME(?)	Pb, Zn, Ba, Ag	The Roman showing consists of disseminated and vein sulphides of epigenetic and possibly sedex origin
	094M 016 Boya Main Face		586460	6566920	PCs, PCc	W, Mo, Cu, Zn, Pb, Bi	The Boya Main Face prospect is primarily a tungsten-molybdenum stockwork-skarn deposit
	094M 021 Boya West Hill		583675	6568860	PCs, PCc	W, Mo, Cu, Zn, Pb, Bi	The Boya West Hill prospect is primarily a tungsten-molybdenum stockwork-skarn deposit

massive orebody, reflecting the distance from the vent source and the role temperature plays in the solubility of the various minerals. Generally the Pb:Zn ratio is highest over and adjacent to the stockwork system and falls off towards the periphery. These ratios have been used to infer the probable location of the stockwork system where it is not recognized (*ie.* Cirque; Pigage, 1986). Pyrite, barite, and rarely pyrrhotite, are the principal non-ore minerals associated with sphalerite and galena. Pyrite and pyrrhotite are concentrated near the vent system whereas barite becomes dominant towards the periphery of the orebodies. Barite may also form a cap over the sulphide body, suggesting that the temperature of the vent system waned before shutting off.

Barite is a significant component of these deposits and is commonly the only chemical sediment at their outer edges. In many areas of Upper Devonian stratigraphy within the Selwyn and Kechika basins, only bedded barite occurrences are found, suggesting only low-temperature vent systems were active in the area. Alternatively, these occurrences may be peripheral to a large, higher temperature vent system and indicate the proximity of a nearby massive sulphide body.

The low-temperature characteristics of these deposits generally means that, beyond the feeder system, they lack a pervasive alteration assemblage in surrounding sediments. In many cases, such as the Cirque or Howards Pass deposits, where feeder systems are not recognized, no visible alteration halos are recognized in adjacent rocks. At the Tom deposit, alteration, in the form of ankerite, siderite and calcite veining, is confined to an underlying stockwork system assumed to be the feeder zone. At the nearby Jason deposit, bleached, crosscutting, silicified and carbonatized alteration zones, associated with quartz, siderite, ankerite and sulphide stockwork systems, have been recognized stratigraphically below various parts of the massive sulphides. Alteration may also occur locally within the massive ore and can be weakly developed in overlying sediments. In the Anvil district, many of the deposits are enveloped by a prominent, light coloured, sericite-muscovite alteration assemblage, in some cases accompanied by silicification and calcification. The present mineralogy of this assemblage is the result of regional greenschist to amphibolite-grade metamorphism. It is usually best developed in the footwall, although alteration is strongest in the hangingwall of the Faro orebody. No feeder system has been recognized at any of the deposits in this camp.

One of the distinguishing features of these deposits is the laminated nature of ore and gangue minerals. Sphalerite, galena, barite and pyrite form finely interlayered sequences with some beds traceable for considerable distances. Clastic, gangue material is commonly found within these horizons. Bedded ore displays many features indicative of deposition from the water column by either chemical or mechanical means. Finely laminated ore is believed to have formed by precipitation of sulphides from the water column. These bedded ores may also display soft-sediment deformation features.

DEPOSITIONAL MODEL

Sedex deposits form by the venting of relatively hot, metalliferous fluids onto the seafloor with subsequent precipitation of ore minerals. Mineral deposition occurs in starved, anoxic basinal settings in the absence of any sub-

TABLE 5A
LITHOGEOCHEMICAL ANALYSES OF MINERALIZED SAMPLES FROM THE SOUTHERN MAP AREA
MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 2

Map Number	Field Number	Easting	Northing	Description	Units	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %
					Detection Limit	1	1	3	1	0.3	1	1	2	0.01	2	5	2	1	0.2	2	2	1	0.01	0.001
1	FFE95-1-7-3	621320	6499390	Pyritiferous quartz vein in PGl..		2	48	29	7	0.9	33	250	< 5	37.45	35	< 10	2	5	< .4	< 5	< 5	8	0.06	0.034
2	FFE95-5-13-2	622807	6499470	Disseminated galena in sheared slate Pcq.		< 2	67	48815	5551	30.1	7	71	29	1.14	32	< 10	3	37	18.8	35	< 5	49	0.55	0.326
3	FFE95-18-13	615228	6506061	Malachite staining on green and maroon slates of CPs.		4	2040	< 5	148	2.2	46	24	1019	5.54	< 5	< 10	16	96	< .4	< 5	< 5	51	0.38	0.036
4	FFe94-10-19-2	637390	6492250	Disseminated chalcopyrite in quartz vein of Cc.		3	8640	< 4	257	1.2	10	156	38	0.24	225	< 10	< 2	< 2	2.5	20	8	2	0.14	0.011
5	JN94-16-5	627190	6495960	Baritic? tuff in lower Road River slates.		< 2	43	66	121	0.7	69	202	237	9.5	5	< 10	4	50	< .4	9	< 4	30	2.14	0.014
6	FFE95-43-7-3A	610069	6526343	Gossanous breccia within OSRR, Smoke (MINFILE 094) showing.		29	101	58	2136	1.1	144	50	460	22.02	52	17	5	84	9.3	31	< 5	49	0.17	0.076
7	FFE95-43-7-3B	610069	6526343	Breccia within OSRR, Smoke (MINFILE 094)		2	225	20	33922	9.1	30	16	471	1.9	12	< 10	3	60	552.4	76	< 5	40	4.01	0.024
8	FFe94-18-8	632290	6497800	Bedded barite, DME		6	40	< 4	143	0.8	39	43	14	1.63	15	< 10	4	168	2.2	11	< 4	234	0.04	0.039
9	FFe94-24-13	632642	6501588	Ferricrete, DME. Near Solo MINFILE locality (094M 015)		19	39	11	7233	1	342	86	1239	5.36	32	< 10	3	375	59.5	21	< 4	185	1.31	0.568
10	FFe94-25-5	633765	6501750	Baritic shale, DME. Near Solo MINFILE locality (094M 015)		4	39	8	80	< .3	51	54	32	4.41	< 4	< 10	3	114	< .4	5	< 4	228	0.08	0.054
11	FFe94-27-15	631745	6498860	Baritic shale, DME		< 2	61	6	95	0.8	23	193	67	3.54	< 4	< 10	6	14	< .4	4	< 4	96	0.01	0.016
12	FFe94-29-13	634700	6500025	Copper-barite quartz vein, DME		< 2	2423	< 4	515	20.2	3	66	35	0.03	36	< 10	< 2	3390	22.2	691	< 4	27	4.63	0.003
13	FFe94-38-3-1	637640	6493850	Ferricrete, DME		51	6	< 4	51933	< .3	3364	141	3639	5.23	29	< 10	< 2	634	320.2	5	5	5	24.48	0.006
14	JN94-9-4	643750	6486740	Ferricrete, DME-SDRR fault contact.		19	42	4	140	2.4	31	110	102	0.83	12	< 10	3	33	1.6	22	4	798	0.17	0.095
15	CRE95-7-18	628239	6500819	Pyritic, slaty siltsone, DME		< 2	12	16	44	0.5	12	13	244	2.55	< 5	< 10	6	130	0.5	< 5	< 5	40	6.55	0.038
16	CRE95-9-9	627789	6501914	Bedded baritic siltstone, DME		3	19	< 5	38	0.7	3	42	18	0.93	< 5	< 10	3	215	< .4	< 5	< 5	212	0.03	0.033
17	JN95-4-1	630459	6503926	Laminated to massive barite in mudstone, DME		2	19	30	212	< .5	56	26	120	4.07	5	< 10	8	99	1.1	< 5	< 5	127	0.15	0.07
18	FFE95-12-2	625301	6506311	Calcareous barite in limestone and cherty argillite, DME		2	17	134	106	< .5	9	100	18	0.15	< 5	15	2	3880	1	8	< 5	119	1.55	0.697
19	FFE95-13-1-1	624952	6507121	Regolith above Broken Bit Barite kill zone, DME		3	16	< 5	132	< .5	21	17	85	0.98	< 5	< 10	< 2	790	1.5	< 5	< 5	131	0.15	0.041
20	FFE95-13-1-2A	624952	6507121	Massive to crudely bedded barite, Broken Bit Barite kill zone, DME		< 2	4	< 5	36	< .5	5	16	< 5	0.15	< 5	10	< 2	555	0.5	< 5	< 5	25	0.29	0.007
21	FFE95-13-1-2B	624952	6507121	Massive, calcareous barite, Broken Bit Barite kill zone, DME		3	11	< 5	93	< .5	15	11	93	0.68	< 5	< 10	< 2	1576	1	< 5	< 5	55	9.33	0.02
22	FFE95-27-7	622307	6509323	Galena-bearing quartz-vein in DME		< 2	64	31390	1412	15.7	10	98	91	1.43	25	< 10	4	31	14	27	< 5	57	0.65	0.026
23	FFE95-22-6	626692	6510167	Bedded calcareous bedded barite, DME		2	10	< 5	65	1	< 2	119	20	0.21	< 5	47	3	5291	0.5	8	< 5	54	0.51	0.129
24	FFE95-22-10	626081	6510860	Calcareous bedded barite, DME. Near Mat MINFILE locality (094M 019)		3	21	< 5	133	1.1	9	120	20	0.17	10	34	3	3717	< .4	10	< 5	101	0.54	0.253
25	FFE95-23-7	623462	6512209	Several horizons of barite rosettes within pyritiferous slates and siltstones of DME		7	38	10	111	0.9	17	13	428	4.79	< 5	< 10	3	482	1.1	9	< 5	169	10.56	0.198
26	CRE95-26-3-3	624244	6515650	Pyritic slate to siltstone, OSRR		< 2	28	25	40	< .5	18	83	33	4.95	5	11	6	67	< .4	< 5	< 5	54	0.07	0.043
27	CRE95-38-1-2	614764	6521890	Bedded, calcareous barite in slates of DME		< 2	5	< 5	67	0.7	< 2	104	20	0.06	< 5	40	3	3290	0.6	7	< 5	83	0.49	0.027
28	FFE95-46-1	616001	6525779	Bedded, calcareous barite in argillites of DME		28	7	8	97	< .5	23	32	11	0.14	< 5	14	< 2	3599	1.8	< 5	< 5	25	0.37	0.058
29	JN95-13A-12	615175	6527225	Disseminated pyrite in siliceous slate of DME		11	39	7	110	0.7	31	64	8	1.19	63	< 10	3	106	< .4	< 5	< 5	233	0.11	0.095

TABLE 5A CONTINUED

Map Number	Field Number	Easting	Northing	Description	Units	La	Cr	Mg	Ba	Ti	Al	Na	K	W	Zr	Sn	Y	Nb	Be	Sc	Au
						ppm	ppm	%	ppm	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb
					Detection Limit	1	1	0.01	1	0.01	3	0.01	0.01	0.01	2	2	2	2	1	1	2
1	FFE95-1-7-3	621320	6499390	Pyritiferous quartz vein in =Gf..		2	6	0.05	522	< .01	0.39	< .01	0.19	453	7	< 2	2	< 2	14	< 1	2
2	FFE95-5-13-2	622807	6499470	Disseminated galena in sheared slate =cq.		4	14	0.02	545	< .01	0.58	0.01	0.22	501	5	< 2	5	2	< 1	< 1	< 2
3	FFE95-18-13	615228	6506061	Malachite staining on green and maroon slates of \=s.		56	60	1.78	1154	0.25	10.57	0.36	2.93	95	58	< 2	11	22	2	15	4
4	FFe94-10-19-2	637390	6492250	Disseminated chalcopyrite in quartz vein of \c.		< 2	5	0.07	44	< .01	0.25	0.01	0.11	889	< 2	< 2	< 2	< 2	< 1	< 1	2
5	JN94-16-5	627190	6495980	Baritic? tuff in lower Road River slates.		6	25	1.54	1928	0.09	3.59	0.43	1.87	248	22	< 2	5	2	< 1	6	25
6	FFE95-43-7-3A	610069	6526343	Gossanous breccia within OSRR, Smoke (MINFILE 094) showing.		9	30	0.22	20702	0.09	2.52	0.02	0.96	66	25	< 2	11	3	1	4	9
7	FFE95-43-7-3B	610069	6526343	Breccia within OSRR, Smoke (MINFILE 094)		6	39	1.64	9840	0.12	2.9	0.03	1.26	173	23	< 2	9	4	1	5	8
8	FFe94-18-8	632290	6497800	Bedded barite, DME		8	26	0.02	151729	0.16	3.53	0.05	1.07	276	43	< 2	7	6	1	5	2
9	FFe94-24-13	632642	6501588	Ferricrete, DME. Near Solo MINFILE locality (094M 015)		8	55	0.13	4195	0.04	1.84	0.01	0.21	269	29	< 2	57	< 2	< 1	4	2
10	FFe94-25-5	633765	6501750	Baritic shale, DME. Near Solo MINFILE locality (094M 015)		5	47	0.06	105984	0.29	5.71	0.36	1.86	207	42	< 2	5	6	1	10	22
11	FFe94-27-15	631745	6498960	Baritic shale, DME		7	69	0.3	2367	0.15	4.12	0.03	1.71	131	27	< 2	4	5	< 1	8	2
12	FFe94-29-13	634700	6500025	Copper-barite quartz vein, DME		< 2	4	0.11	187805	< .01	0.12	0.01	0.01	234	< 2	< 2	< 2	< 2	< 1	< 1	6
13	FFe94-38-3-1	637640	6493850	Ferricrete, DME		< 2	41	0.31	385	< .01	0.15	0.02	0.03	4	3	< 2	12	< 2	< 1	< 1	3
14	JN94-9-4	643750	6486740	Ferricrete, DME-SDRR fault contact.		8	48	0.19	1454	0.08	1.45	0.01	0.6	812	25	< 2	8	3	< 1	4	3
15	CRE95-7-18	628239	6500819	Pyritic, slaty siltsone, DME		15	30	3.84	1766	0.14	3.64	0.19	1.71	139	22	< 2	8	4	< 1	6	< 2
16	CRE95-9-9	627789	6501914	Bedded baritic siltstone, DME		7	21	0.03	27.36%	0.13	2.31	0.03	1.04	54	22	< 2	4	6	< 1	5	3
17	JN95-4-1	630459	6503928	Laminated to massive barite in mudstone, DME		22	69	0.94	5612	0.3	5.78	0.62	1.25	342	48	< 2	10	8	1	13	< 2
18	FFE95-12-2	625301	6506311	Calcareous barite in limestone and cherty argillite, DME		4	17	0.01	44.19%	< .01	0.39	< .01	0.07	41	4	< 2	9	< 2	< 1	1	< 2
19	FFE95-13-1-1	624952	6507121	Regolith above Broken Bit Barite kill zone, DME		4	11	0.08	41.48%	0.07	1.92	0.19	0.42	28	14	< 2	5	3	< 1	4	< 2
20	FFE95-13-1-2A	624952	6507121	Massive to crudely bedded barite, Broken Bit Barite kill zone, DME		< 2	< 2	0.01	47.91%	< .01	0.3	0.08	0.04	14	2	< 2	< 2	< 2	< 1	< 1	< 2
21	FFE95-13-1-2B	624952	6507121	Massive, calcareous barite, Broken Bit Barite kill zone, DME		3	11	0.12	25.29%	0.03	1.24	0.01	0.09	32	8	< 2	4	< 2	< 1	3	< 2
22	FFE95-27-7	622307	6509323	Galena-bearing quartz-vein in DME		7	17	0.3	1157	0.08	2.01	0.02	0.79	888	13	< 2	4	2	< 1	4	2
23	FFE95-22-6	629892	6510167	Bedded calcareous bedded barite, DME		< 2	6	0.01	43.37%	0.01	0.3	0.07	0.14	40	3	< 2	4	2	1	< 1	< 2
24	FFE95-22-10	626081	6510850	Calcareous bedded barite, DME. Near Mat MINFILE locality (094M 019)		< 2	18	0.01	38.55%	0.01	0.38	< .01	0.15	52	7	< 2	9	3	1	1	< 2
25	FFE95-23-7	623462	6512209	Several horizons of barite rosettes within pyritiferous slates and siltstones of DME		10	41	0.09	10481	0.12	3.09	0.28	1.59	103	28	< 2	13	5	< 1	8	3
26	CRE95-26-3-3	624244	6515650	Pyritic slate to siltstone, OSRR		26	58	1.41	12383	0.28	6.28	0.82	2.29	155	33	< 2	6	9	2	11	9
27	CRE95-39-1-2	614794	6521890	Bedded, calcareous barite in slates of DME		< 2	< 2	0.03	48.38%	< .01	0.13	< .01	0.08	11	4	< 2	< 2	2	1	< 1	< 2
28	FFE95-48-1	616001	6525779	Bedded, calcareous barite in argillites of DME		3	6	0.02	48.34%	< .01	0.24	0.01	0.08	8	6	< 2	3	< 2	< 1	< 1	2
29	JN95-13A-12	615175	6527225	Disseminated pyrite in siliceous slate of DME		7	43	0.08	3271	0.05	1.35	0.04	0.44	759	11	< 2	3	4	< 1	2	9

All elements by AICP ($HClO_4$-HNO_3-HCl-HF-inductively-coupled plasma emission spectroscopy). except Ba XRF (x-ray fluorescence, pressed pellet) and Au FA (fire assay). Possible Fe contamination in milling. %: per cent; ppm: parts per million; ppb: parts per billion

TICP, FA - ACME Analytical Laboratories, Vancouver, B.C. XRF - Cominco Research Laboratories, Vancouver, B.C.

TABLE 5B
LITHOGEOCHEMICAL ANALYSES OF MINERALIZED SAMPLES FROM THE NORTHERN MAP AREA
MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 3

Map Number	Field Number	Easting	Northing	Description	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
					1	1	3	1	0.3	1	1	2	0.01	2	5	2	2	1	0.2
1	FFE96-7-4-2	582374	6554085	Rusty limestone in slates of DME	1	14	11	87	0.2	23	1	640	0.49	17	< 5	< 2	< 2	950	1.1
2	FFE96-19-4	580642	6592737	Layer-parallel pyrite horizons in ODrk	83	100	30	384	1	16	5	86	18.84	88	< 5	< 2	< 2	16	2.6
3	FFE96-19-4b	580642	6592737	Smithsonite-bearing calcite vein in ODrk	6	25	6	30819	0.5	4	1	435	1.08	< 2	< 5	< 2	< 2	794	330.7
4	FFE96-25-11	580207	6541353	Layer-parallel pyrite horizons in ODrk	2	40	9	181	< 3	38	10	1142	8.75	10	< 5	< 2	2	288	< 2
5	CRE96-8-6	573298	6570067	Rusty white quartz vein in calcareous slate of PPsc	14	118	70	325	4	16	2	13	0.94	66	7	< 2	2	101	2.3
6	CRE96-17-3	568413	6604780	Calcareous and baritic siltstone to silty limestone in ODrk	3	8	< 3	173	0.3	22	2	96	0.30	3	< 5	< 2	< 2	550	6.6
7	CRE96-17-6-1	570318	6605220	Sphalerite, malachite and galena?-bearing quartz-carbonate veins in fetid limestone of ODrk	1	27	3	4187	0.3	7	1	20	0.15	3	< 5	< 2	< 2	1443	98.8
8	CRE96-19-7-2	584707	6589096	Rusty quartz vein in gossanous slates of DME?	1	6	< 3	19	< 3	4	< 1	19	1.09	19	< 5	< 2	< 2	30	< 2
9	CRF96-25-3	602050	6541140	Pyritic siltstone, argillite in DME	3	30	17	67	< 3	42	11	307	2.66	51	< 5	< 2	2	65	< 2
10	JHA96-11-3	578274	6585350	Bedded to massive barite with pyritiferous slate of DME Kechika River Barite	2	17	8	108	< 3	21	8	263	1.80	4	5	< 2	< 2	257	3.8
11	JHA96-15-5	587432	6578774	Pyrite-bearing quartz veins in phyllite of PPsc	3	8	7	187	< 3	9	4	286	2.12	< 2	< 5	< 2	< 2	108	1.6

Map Number	Field Number	Easting	Northing	Description	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Au
					ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppb
					3	3	1	0.01	0	1	1	0.01	5	0.01	3	0.01	0.01	0.01	2	2
1	FFE96-7-4-2	582274	6554085	Rusty limestone in slates of DME	< 2	< 2	138	21.11	0.078	1	61	12.48	611	< .01	3	0.05	0.01	0.01	< 2	6
2	FFE96-19-4	580642	6592737	Layer parallel pyrite horizons in ODrk	< 2	< 2	8	1.84	0.004	1	39	0.06	22710	< .01	< 3	0.04	0.01	0.09	< 2	5
3	FFE96-19-4b	580642	6592737	Smithsonite bearing calcite vein in ODrk	< 2	2	14	20.45	0.008	11	22	1.85	47874	< .01	< 3	0.07	< .01	0.01	< 2	8
4	FFE96-25-11	580207	6541353	Layer parallel pyrite horizons in ODrk	2	< 3	11	5.39	0.008	4	44	2.32	3813	< .01	< 3	0.24	0.01	0.05	< 2	4
5	CRE96-8-6	573298	6570067	Rusty white quartz vein in calcareous slate of PPsc	27	< 3	167	0.81	0.251	3	79	0.55	1236	< .01	6	0.28	< .01	0.15	< 3	6
6	CRE96-17-3	568413	6604785	Calcareous and baritic siltstone to silty limestone in ODrk	< 3	< 2	20	27.85	0.034	12	88	0.32	2379	< .01	< 3	0.2	< .01	0.04	< 3	< 2
7	CRE96-17-6-1	570318	6605220	Sphalerite, malachite and galena?-bearing quartz carbonate veins in fetid limestone of ODrk	7	< 3	96	28.00	0.02	8	85	0.53	1166	< .01	< 3	0.03	< .01	< .01	< 3	6
8	CRE96-19-7-2	584707	6589096	Rusty quartz vein in gossanous slates of DME?	< 2	< 2	84	0.11	0.101	2	135	0.01	812	< .01	< 3	0.12	< .01	0.09	< 2	11
9	CRE96-25-3	602050	6541148	Pyritic siltstone, argillite in DME	< 2	< 2	9	5.88	0.034	4	28	2.83	1078	< .01	5	0.20	< .01	0.2	< 2	50
10	JHA96-11-3	578274	6585350	Bedded to massive barite with pyritiferous slate of DME Kechika River Barite	3	< 2	11	0.86	0.076	2	14	0.33	4E+05	< .01	< 3	1.15	< .01	0.06	< 2	< 2
11	JHA96-15-5	587432	6578774	Pyrite-bearing quartz veins in phyllite of PPsc	< 2	< 2	4	2.82	0.081	2	51	0.06	268	< .01	< 3	0.05	0.01	0.03	< 2	< 2

All elements by AICP (HClO$_4$-HNO$_3$-HCl-HF inductively coupled plasma emission spectroscopy), except Ba XRF (x-ray fluorescence, pressed pellet) and Au FA (fire assay). Possible Fe contamination in milling. %: per cent; ppm: parts per million; ppb: parts per billion
ICP, FA - ACME Analytical Laboratories, Vancouver, B.C. XRF - Cominco Research Laboratories, Vancouver, B.C.

TABLE 5C
STREAM SEDIMENT AND SOIL ANALYSES FOR SELECTED SITES FROM THE SOUTHERN MAP AREA
MAP NUMBERS REFER TO LOCALITIES PLOTTED ON FIGURE 2

Stream Sediment Analysis***

Map Number	Field Number	Easting	Northing	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb
				ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	GAT94-001	643750	6488774	4	26	20	283	0.4	41	9	208	3.2	7	< 5	< 2	7	37	2.3	5
2	GAT94-002	647410	6486550	11	35	26	943	0.2	95	14	324	3.74	12	< 5	< 2	8	33	6.4	3
3	GAT94-002	642300	6487200	6	51	27	431	0.3	77	16	302	3.77	8	< 5	< 2	8	50	3.3	3
4	GAT94-003	642825	6486575	30	189	12	3775	0.7	610	88	2419	11.24	25	16	< 2	3	101	30.8	5
5	GAT94-004	627250	6498525	16	61	52	881	0.8	98	11	248	2.45	16	< 5	< 2	3	57	6.3	6
6	GAT94-006	626180	6498750	5	43	34	837	0.6	59	9	194	2.33	19	< 5	< 2	4	75	4.9	6

Map Number	Field Number	Easting	Northing	Bi	V	Ca	P	La	Cr	Mg	Ba***	Ti	B	Al	Na	K	W	Au****
				ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppb
1	GAT94-001	643750	6488774	< 2	78	0.92	0.083	36	24	1.59	1820	< .01	4	1.76	< .01	0.12	< 1	9
2	GAT94-002	647410	6486550	< 2	59	0.82	0.067	16	22	0.74	1109	< .01	2	1.3	< .01	0.06	< 1	1
3	GAT94-002	642300	6487200	< 2	31	0.55	0.09	19	22	0.67	1590	0.01	3	1.35	< .01	0.07	< 1	1
4	GAT94-003	642825	6486575	2	82	1.61	0.195	18	26	0.5	1844	0.01	< 2	1.3	0.01	0.2	< 1	7
5	GAT94-004	627250	6498525	< 2	66	3.51	0.145	23	14	1.38	1679	< .01	2	0.5	< .01	0.08	< 1	4
6	GAT94-006	626180	6498750	< 2	20	4.32	0.1	19	7	2.38	1543	< .01	2	0.34	< .01	0.07	< 1	2

Soil Analysis***

Map Number	Field Number	Easting	Northing	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb
				ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
a	94JN9-4	643750	6488740	50	1233	11	2815	1.9	858	161	3431	15.17	71	31	< 2	4	119	26.3	16

All elements except Ba were analyzed by Acme Analytical Laboratories Ltd., 852 Hastings St., Vancouver, B.C., V6A 1R6
Ba analysis from Cominco Exploration Research Laboratory, 1486 East Pender St., Vancouver, B.C., V5L 1V8
*Samples digested in 10 ml HClO$_4$-HNO$_3$-HCl-HF and analyzed by ICP method.
**Samples digested in 3 ml 3-1-2 HCl-HNO$_3$-H$_2$O and analyzed by ICP method.
***Element anaylzed by XRF.
**** Element analyzed by fire assay.

TABLE 6
TYPICAL GRADE AND TONNAGES FOR PALEOZOIC SEDEX MSSIVE SULPHIDE DEPOSITS WITHIN THE KECHIKA AND SELWYN BASINS

Age	Name	Size (million tonnes)	Zn (per cent)	Pb (per cent)	Cu (per cent)	Ag (grams per tonne)	Au (grams per tonne)
Cambro-Ordovician	Swim[1]	4.3	4.7	3.8		42	
Cambro-Ordovician	Grum[1]	30.8	4.9	3.1		49	
Cambro-Ordovician	Dy[1]	21.1	6.7	5.5	0.12	84	0.95
Cambro-Ordovician	Vangorda[1]	7.1	4.3	3.4		48	
Cambro-Ordovician	Faro[1]	57.6	4.7	3.4		36	
Early Silurian	Howards Pass District[2]	425	5	2		9	
Late Devonian	Cirque	38.5	8	2.2		47.2	
Late Devonian	South Cirque	15.5	6.9	1.4		32	
Late Devonian	Driftpile Creek	2.4	11.9	3.1			
Late Devonian	Tom	15.7	7	4.6		49.1	
Late Devonian	Jason	15.5	6.6	7.1		79	

[1] Anvil District

[2] Anniv and XY

Data from MacIntyre (1991), Lydon (1985), Goodfellow and Jonsson (1986)

stantial coeval igneous activity. Work on Late Devonian sedex deposits in the Macmillan Pass area of the Yukon has shown that they are located within a syndepositional pull-apart basin (Abbott, 1982; Turner and Rhodes, 1990). Some deposits, particularly the Jason, thicken toward a bounding synsedimentary fault which controls the associated underlying stockwork feeder system (Turner *et al.*, 1989; Bailes *et al.*, 1986).

These relationships suggest that extension during the Late Devonian led to the formation of graben and half-graben structures. Some of the bounding faults channeled mineralizing fluids, localizing stockwork systems and associated mineralization at graben boundaries (Figure 20). Graben development within these anoxic basins led to the local formation of syn-mineralization sedimentary breccias (Turner *et al.*, 1989). Similar relationships are envisioned for the Cirque and related deposits in the Gataga district of the southern Kechika Trough (MacIntyre, 1998), where extensional tectonism led to the development of linear reefs of Devonian age. Ore deposition occurred within the down-thrown blocks and is believed to have been controlled by bounding faults.

A somewhat different model is envisioned for the Howards Pass deposits where no feeder zone is recognized and the host basin lacks any evidence of extensional tectonism or high heat flow. Morganti (1981) suggested that metal-rich fluids were sourced from vents along the platform-basin contact, where the presence of coeval volcanics indicate tectonic activity. These strongly saline and dense fluids then migrated down the paleoslope and ponded in sub-basins located between the base of the slope and the main basin. Sulphide minerals then precipitated from this dense, metalliferous brine pool.

The above model leads to a fundamental discussion about the process by which ores precipitated from the venting fluids and formed sedimentary exhalative ore deposits (*see* Lydon, 1996 for detailed discussion). The brine pool model, briefly described above, envisions that ore and gangue minerals precipitated from a dense, metal-rich, stagnant, brine pool formed by the ponding of hydrothermal solutions either in topographic lows near the vents or by the migration of these fluids along the seafloor to nearby depressions. This process readily explains the laterally continuous, laminated nature of the ore and the localization of many of these deposits in smaller depressions or sub-basins. Turner *et al.* (1989), using strontium isotopes and comparison with modern brine pool environments, showed that barite at the Jason deposit most likely formed from precipitation within such a brine pool.

Opponents to this model cite fluid-inclusion data which show that salinities are not high enough for the average calculated temperature of hydrothermal effluents to form a fluid denser than sea water. Instead, this fluid would most likely have formed a buoyant plume which would spread from the vent area and lead to the dispersal of ore minerals. This model requires periods with a stratified ocean-water column whereby bottom waters remain anoxic allowing the precipitation and non-oxidation of sulphides.

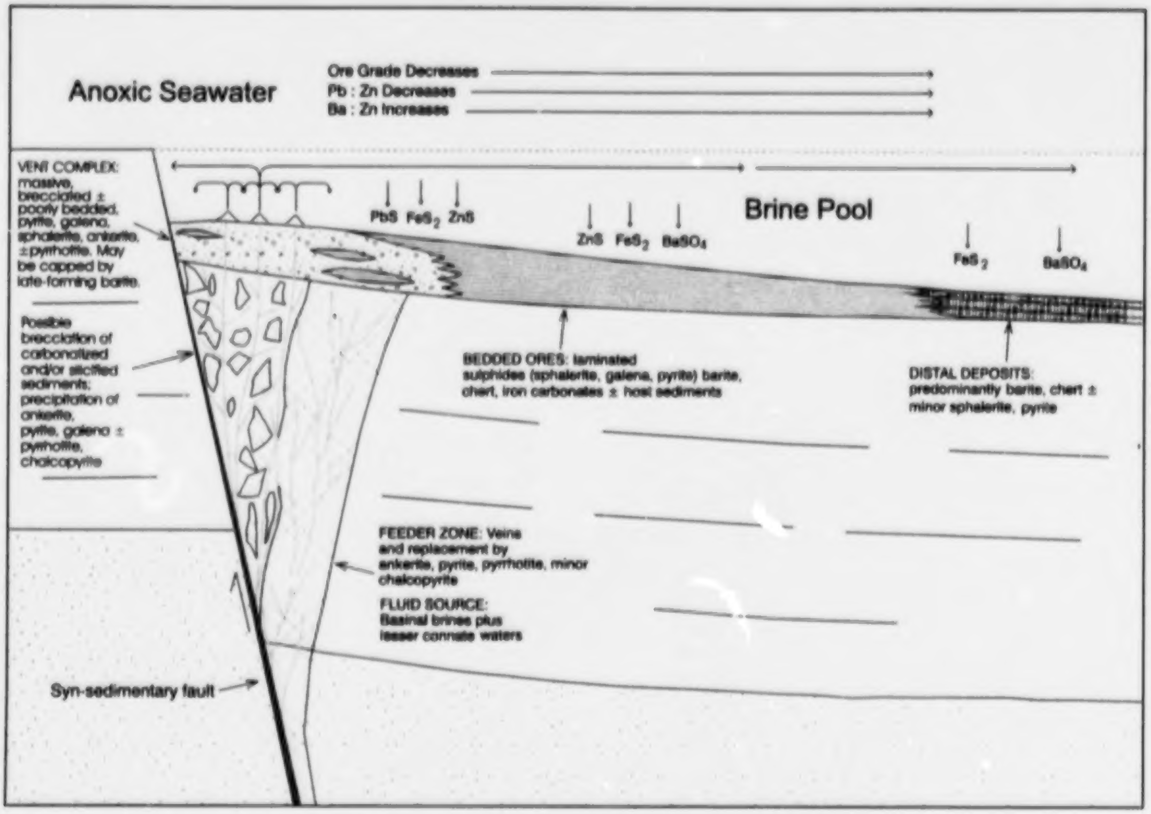

Anoxic Seawater
Ore Grade Decreases
Pb : Zn Decreases
Ba : Zn Increases
VENT COMPLEX: massive, brecciated ± poorly bedded, pyrite, galena, sphalerite, ankerite, ± pyrrhotite. May be capped by late-forming barite.
Possible brecciation of carbonatized and/or silicified sediments; precipitation of ankerite, pyrite, galena ± pyrrhotite, chalcopyrite
PbS FeS$_2$ ZnS
ZnS FeS$_2$ BaSO$_4$
Brine Pool
FeS$_2$ BaSO$_4$
BEDDED ORES: laminated sulphides (sphalerite, galena, pyrite) barite, chert, iron carbonates ± host sediments
DISTAL DEPOSITS: predominantly barite, chert ± minor sphalerite, pyrite
FEEDER ZONE: Veins and replacement by ankerite, pyrite, pyrrhotite, minor chalcopyrite
FLUID SOURCE: Basinal brines plus lesser connate waters
Syn-sedimentary fault

Figure 20. Schematic representation of a typical sedimentary exhalative mineralizing system in Lower Paleozoic rocks of the Selwyn and Kechika basins. Modified from: Lydon (1996), MacIntyre (1991), Turner *et al.* (1989).

The ore-forming fluids are believed to be derived from the underlying sedimentary sequence. The lack of igneous activity and relatively low temperature of the ore systems also suggests to many that mineralizing fluids are formational waters, discharged to the surface when extensional faults tapped over-pressured and porous sedimentary horizons in an area of anomalously high heat-flow (Carne and Cathro, 1982; Goodfellow and Jonasson, 1986). Using calculated temperatures of original hydrothermal fluids, together with anomalous geothermal gradients, these authors argue that metallic and non-metallic minerals could have been derived from the thick sections of Late Proterozoic sediments that underlay the Selwyn and Kechika basins at greater than 3 kilometres depth. A basic problem in this model is explaining the higher salinities (over 2.5 times that of normal sea water) found during fluid-inclusion work (Gardner and Hutcheon, 1985) or required in the brine pool model. Lydon (1996) and Goodfellow *et al.* (1993) suggest that a prerequisite in any sedex province is the presence of evaporitic deposits in the stratigraphic sequence which would have increased the salinity of formational fluids as they penetrated these evaporitic horizons.

Several sedex and related deposits in the Selwyn and Kechika basins are associated with minor occurrences of volcanic rocks. These include the Boundary Creek deposit of MacMillan Pass (Turner and Rhodes, 1990), the Cirque deposit (Pigage, 1986) and the Anvil camp (Jennings and Jilson, 1986). Although a direct link between volcanism and mineralization is difficult or impossible to prove, associated igneous activity would provide a way of generating the temperatures required to produce these deposits (approximately 250°C). The higher or anomalous geothermal gradients within the hosting basins postulated in many genetic models may simply reflect localized intrusive centres buried at depth. This suggestion is particularly appealing for Earn-hosted sedex deposits, which are coeval with widespread Late Devonian to Early Mississippian igneous activity within more western cratonic and peri-cratonic rocks of Ancestral North America. Furthermore, the exhalative nature of both sedex and volcanogenic massive sulphide (VMS) deposits suggests they can be viewed as end members of an ore-forming system where one of the variables is the amount of volcanic material in the hosting rock sequence. Besshi-type deposits would then represent median deposit types. In many cases, as MacIntyre (1991) pointed out, the classification of a bedded massive sulphide deposit as being either sedex or besshi-type is purely subjective.

EXPLORATION PARAMETERS

One of the most important features of sedex deposits in the Kechika and Selwyn basins is their starved basin, anoxic setting. Black, reduced, organic-rich shales, at specific stratigraphic levels along the ancient western miogeocline, host many of the known deposits. As MacIntyre (1991) pointed out, the presence of barite or disseminations or fine laminations of pyrite are also good indicators of this reducing environment. Slow sedimentation rates insure that these deposits are not diluted by sediment influx. In the study area, these environments are represented by several horizons at specific stratigraphic levels: unit Cs of broadly Cambrian age, Upper Cambrian to Lower Ordovician Kechika Group, Middle Ordovician to Lower Silurian Lower Road River Group and the Upper Devonian Earn Group. These sequences have been delineated in detail over much of the Kechika Trough during this study, by McClay *et al.* (1988) and by MacIntyre (1998) to the south.

As noted previously, some Late Devonian sedex occurrences are localized at the edge of graben or half-graben systems, with the bounding faults having acted as the conduits for mineralizing fluids (Figure 20). This model indicates that sedex mineralization within these larger euxinic basins accumulated within smaller sub-basins; the so called "second or third-order basins". From an exploration standpoint, recognition of these sub-basins is critical to focusing exploration efforts and discovering new occurrences.

In a general sense, the identification of unusual thicknesses of prospective horizons, together with the presence of coarser clastic material that could be related to slumping along fault scarps, may indicate the presence of sub-basins. For example, black slate, chert and limestone of the lower Road River Group (unit OSRR) is typically quite thin (less than 50 metres) in the map area. Thickness increases to over 150 metres including baritic beds, north of Terminus Mountain, suggesting the presence of a sub-basin.

Distinguishing sub-basin bounding faults is another means of zeroing in on perspective sedex environments. Mapping these early extensional features in a structural province now dominated by younger thrust faults is quite challenging. Abbott (1982) demonstrated that early normal faults occur in Late Devonian systems in the MacMillan Pass area and their presence is inferred in the Gataga district from the nearby presence of carbonate buildups on the up-thrown side of the bounding fault (*i.e.* Akie reefs; MacIntyre, 1998). MacIntyre (1991, 1998) also notes that many Late Devonian deposits in the Gataga district are now flanked by thrust faults and suggests that these may be re-activated earlier extension faults.

Proximity to a sub-basin-bounding fault may be indicated not only by the unusual thickness of prospective units, but also by the nature of the deposits. In the southern Kechika Trough, deposits such as Cirque, occur near linear reefs of Devonian age which are assumed to occur on the upthrown side of sub-basin faults. As MacIntyre (1998) shows, clastic carbonate deposits proximal to these reefal structures quickly thin and disappear basinward.

CAMBRIAN?

A few horizons containing authigenic barite crystals, up to 2 centimetres thick, were found within siltstone tentatively assigned to unit Cs along the southern end of Chee Mountain. The presence of this mineralization, although minor, suggests a sedex origin. This is indirectly supported by Middle Cambrian regional extensional tectonism and high heat-flow, evidenced by conglomerate of unit Ccg and volcanics of unit CPv, both key components of any sedex environment. Considering the favourable elements present in these strata, together with the fact that Cambrian sedex mineralization, like that of the Anvil camp, is significant in the northern Cordillera, these rocks may hold potential for larger occurrences.

LATE CAMBRIAN TO EARLY ORDOVICIAN

Green, possibly tuffaceous slate, up to 5 metres thick, is exposed at the base of unit COKR east of Split Top Mountain. Similar slate, although calcareous in part, crops out within the same unit and thrust panel approximately 5 kilometres south of Netson Lake. This horizon is characterized by 1 to 3-centimetre beds containing authigenic barite crystals up to 1 centimetre in size and locally comprising up to 30 per cent of the layer.

The presence of these horizons at the very base of this unit strongly suggests they are part of the Kechika Group and thus Late Cambrian to Early Ordovician in age. Cecile and Norford (1979) also reported scattered nodules of crystalline barite at the base of the Kechika Group in the Ware and Trutch map areas. These occurrences suggest that some form of mineralization (sedex?), possibly related to volcanism and extension, was associated with the initiation of Kechika deposition.

An overturned panel of Kechika or lower Road River slates, exposed along a creek 2 kilometres south of the first large bend in Matulka Creek, contains thin (1 to 3 cm) beds of orange-weathering baritic silty dolostone with authigenic barite crystals. These baritic horizons are interlayered with shales containing graptolites of Arenigian or Tremadocian age (Early Ordovician) and are approximately 30 metres stratigraphically below Silurian siltstone of the Road River Group.

MacIntyre (1998) also notes minor occurrences of barite and phosphorite in silty sections of the Kechika Group in the southern Kechika Trough. His description of this mineralization is very similar to the Early Ordovician mineralization described above.

MIDDLE ORDOVICIAN OR EARLY SILURIAN

Locally (*e.g.* southeast of Brownie Mountain) carbonate horizons in the lower Road River Group contain tiny (0.1 to 5 millimetre) authigenic barite crystals. The stratigraphic position of these occurrences is not well constrained. Considering known Early Silurian sedex mineralization within the upper part of this unit, and the prevalence of Middle Ordovician showings in southern Kechika Trough, the age of these occurrences could be Middle Ordovician or Early Silurian.

One occurrence of black pyritiferous slate with elevated barium levels is of probable Middle Ordovician age. It is located on the west side of a broad syncline, approximately 9.5 kilometres northwest of Netson Lake and consists of rusty weathering, dark grey pyritic slate, silty slate and pale grey, pyritic siltstone (Figure 21; Tables 4a and 5a). Pyrite forms nodules up to 1 or 2 centimetres across; analysis of the slate shows only 1.2 per cent Ba. These rocks are overlain by 5 to 10 metres of interbedded black slaty siltstone to slate, black chert to cherty siltstone and grey, laminated to massive, clastic limestone containing clasts of limestone, black chert and siltstone. The massive limestone sections contain up to 3 per cent disseminated pyrite. A conodont sample from the limestone returned a Late Cambrian to Ordovician age. These lithologies are inconsistent with the Kechika Group and suggest they are part of the lowermost Road River Group.

Regionally, the Middle Ordovician was a period of widespread transgression along the northern part of the ancestral North American miogeocline This event was accompanied by alkalic volcanism, probably linked to extensional tectonism (Gabrielse and Yorath, 1991). These features are conducive to the formation of sedex deposits, but, except for minor occurrences in southern Kechika Trough (MacIntyre, 1998), no major deposits of this type are known.

Nelson Claim Group Area

Hunter Exploration Group staked the ground immediately around a multi-element stream sediment geochemistry anomaly reported by the 1996 RGS survey (Figure 22; Jackaman *et al.*, 1996; Weber and Lehtinen, 1997). Weber and Lehtinen (*op. cit.*) reported anomalous levels of Zn, Ni, Cu, Ag and Ba in silts from a west-flowing creek from the

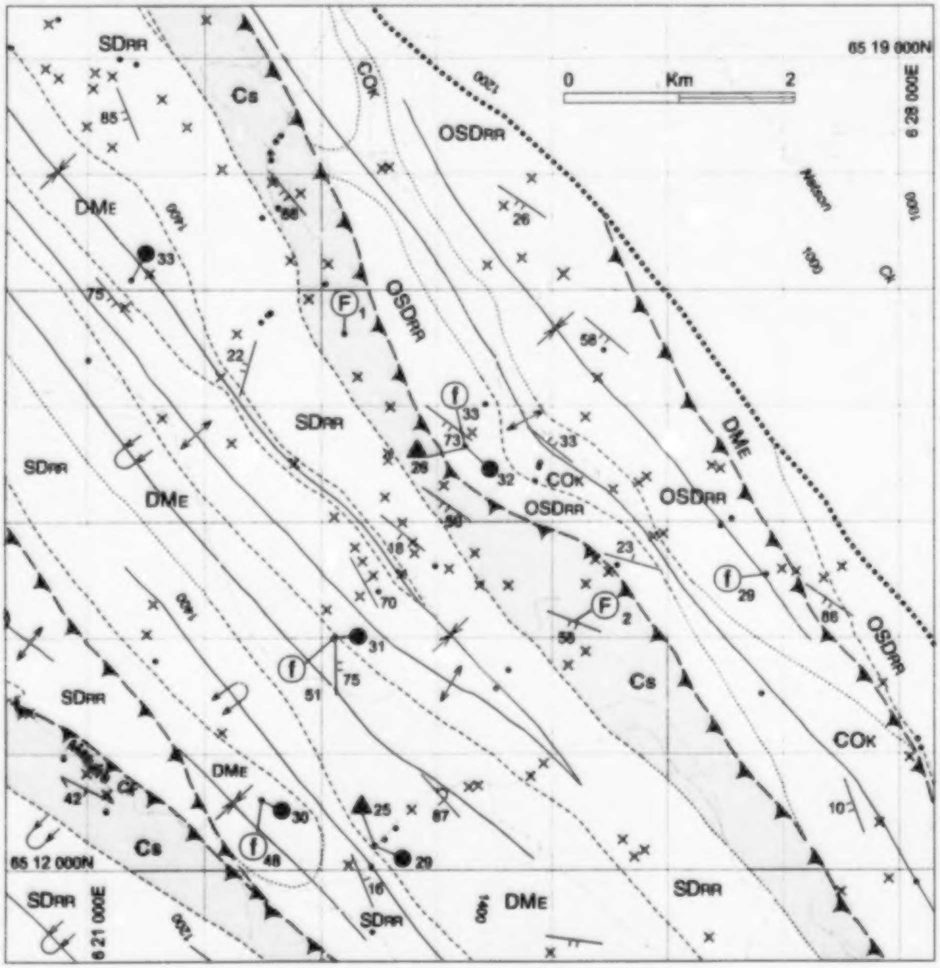


Figure 21. Geology in the vicinity of a barite occurrence located within pyritiferous shales of probable Middle Ordovician age (locality 32). Symbols, linetypes, *etc.* Are idenitical to those found wihtin figures 2 and 3.

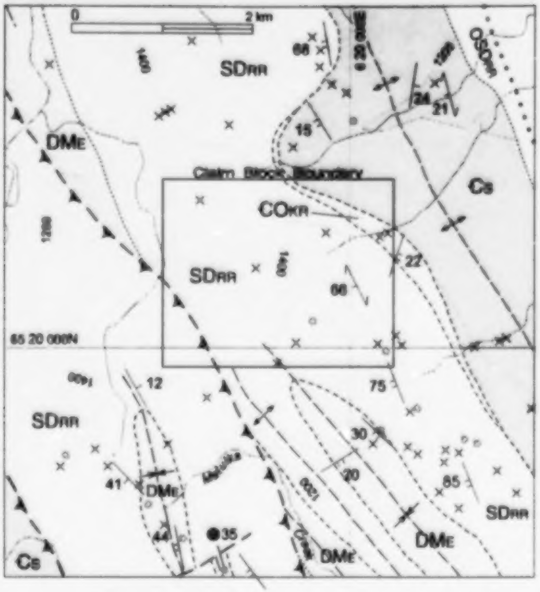


Figure 22. Geology in the vicinity of the Nelson claim block (box). Symbols, linetypes, *etc.* are identical to those found within figures 2 and 3.

centre of the property, verifying results of the 1996 RGS release. They suggest that these anomalies may be linked to Earn lithologies. Although this is a possibility, and lithologies they describe may broadly fit descriptions of the Earn Group, the few exposures seen during this study within the area of the anomalies are more consistent with Road River lithologies. The cherty shale and limestone present at the southeastern corner of the claim block is very similar to the chert-limestone marker seen at the top of the Silurian siltstone member in the southern part of the study area. The cherty shale outcrops reported near the anomalies may belong to the Ordovician or Early Silurian parts of the Road River Group which have been shown to contain bedded barite, and which contain sedex sulphide mineralization elsewhere in the region.

EARLY SILURIAN (094L 041; 094L 042)

A section of black, sooty slate, cherty argillite, silty slate and nodular to bedded limestone is poorly exposed approximately 6 kilometres north of Terminus Mountain (Figure 23). Nodular barite, in beds up to 50 centimetres thick, is interlayered with limestone and silty slate (Photo 70). Barite nodules comprise up to 30 per cent of the layer and are 1 to 5 centimetres in diameter. These rocks were originally assigned to the Earn Group (Ferri *et al.*, 1996b). Subsequent conodont dating indicates the mineralized section is Early Silurian, and that the entire argillaceous sequence is part of the lower Road River Group (*see* Chapter on Lithologic Units). The stratigraphy hosting this occurrence is inferred to extend for some 10 kilometres, although its details are poorly understood due to limited exposure.

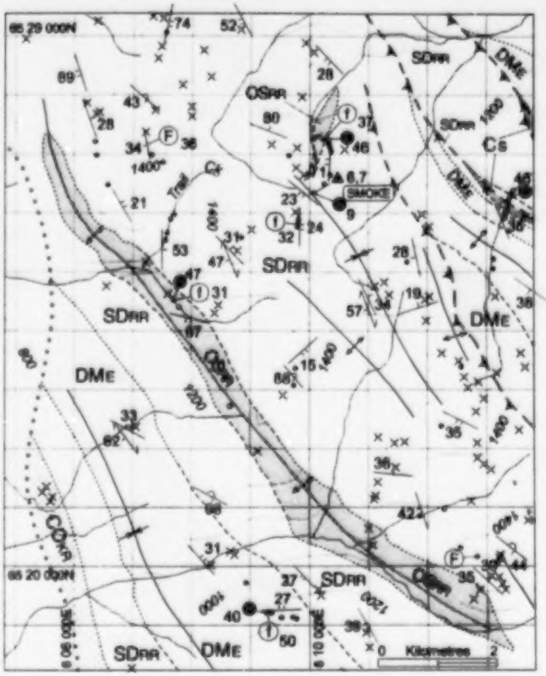


Figure 23. Location of the Early Silurian barite occurrence (locality 47) with respect to area geology. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

A very similar section of this age, and also containing barite mineralization is exposed 13 kilometres due north of Terminus Mountain, along the same ridge as the Smoke mineral showing. This section was also originally believed to be part of the Earn Group, until subsequent conodont dating showed it to be Early Silurian. Limestone is clastic or fragmental at this locality, with clasts of carbonate, chert and barite. Barite rosettes up to 5 millimetres across are also present. Wagner (1997d) reports the presence of a barite-rich layer, 30 centimetres thick, within this section, with 19.4 per cent Ba but negligible base and precious metals.

Early Silurian mineralization is poorly represented within the study area. In the southern Kechika Trough, MacIntyre (1998) describes several Early Silurian Ba-Zn-Pb-Fe sedex occurrences (ERN and CT). They are hosted by Silurian limestone and chert and are located much closer to the ancient miogeoclinal edge.

Perhaps the best known and most significant Early Silurian sedex deposits within the ancient miogeocline are in the Howards Pass area of the Yukon and Northwest Territories (Morganti, 1979, 1981; Goodfellow and Jonasson, 1986; Norford and Orchard, 1983). They are five main occurrences in the Howards Pass area: OP, Anniv, XY, Pab and Hug. These occur within a unit near the top of the lower Road River Formation that is locally called the Active member (Morganti, 1981). It consists of limestone, cherty limestone and carbonaceous cherty mudstone. This sequence occurs just below bioturbated siltstone of the upper Road River Formation and above pyritic, calcareous and carbonaceous mudstones of the lower Road River (Goodfellow and

Photo 70. Barite nodules in Early Silurian argillaceous limestone and argillite assigned to the lower Road River Group, approximately 6 kilometres north of Terminus Mountain.

Jonasson, 1986). The XY and Anniv deposits are by far the largest, with the XY deposit being a lens some 50 metres thick and 3 to 4 kilometres long. Published reserves for the Anniv and XY deposits are 113 million tonnes grading 5 per cent Zn and 2 per cent Pb with a further 363 million tonnes of inferred reserves at similar grade (Goodfellow and Jonasson, 1986). Barite and silver are negligible in these deposits.

Norford and Orchard (1983) carried out a biostratigraphic study of the Road River Formation in the Howards Pass area. Their data indicate that the main mineralizing event in the Active member took place in latest Early to Middle Landovery time (*kentuckyensis* conodont zone and *cyphus* to *convolutus* graptolite zones).

The stratigraphic position, associated lithologies and Early Silurian (Llandovery) age of barite occurrences in our map area suggests correlations with Howards Pass mineralization. This inference is given more weight by the presence of mazuelloids in the microfossil collection from both sites. These rare, enigmatic microfossils morphologically resemble radiolaria but are phosphatic rather than siliceous and lived in lower to middle Paleozoic times. The significance of these microfossils, with respect to Howards Pass mineralization, was pointed out to the authors by M.J. Orchard (personal communication, 1996). Norford and Orchard (1983) noted the presence of mazuelloids at various stratigraphic levels within the slate-chert unit of the Road River Formation and lower parts (Ludlovian) of the Earn Group in the Howards Pass area. They appear at two levels of the Silurian at Howards Pass: in the Llandovery (*celloni* zone), just above the main mineralized horizon, and in the Ludlow (Norford and Orchard, *op. cit.*). These relationships strongly suggest that baritic mineralization in our area is also within the *celloni* conodont zone (middle to late Llandovery) and just above the time-equivalent horizon of Howards Pass mineralization. This argument assumes that mazuelloids occur at the same stratigraphic level in both the Kechika and Selwyn basins.

KITZA CREEK FACIES

Several minor barite and barite-sulphide occurrences of possible sedex origin were encountered in rocks of the Kitza Creek facies. One is located on Kitza Creek, approximately 2 kilometres east of Kitza Lake. The hostrocks are blocky to platy, medium to dark grey or black, fine to medium-grained limy siltstone to silty limestone. There are also thin, pale buff-grey calcareous sandstone beds within the section. No barite was noted, but the calcareous rocks felt slightly heavier than normal, and analysis reveals they are slightly anomalous in barium (0.2 per cent; Tables 4a and 5a).

At a locality on the Red River, bedding-parallel pyritic and gossanous layers, 0.5 to 2 centimetres thick, are found within blocky, interlayered dark, sooty, calcareous siltstone and argillaceous silty limestone. The pyritic layers can be traced for up to 5 metres. A sedex origin is postulated for these horizons, although layer-parallel veining cannot be ruled out. Analysis (Table 5a) shows they are strongly anomalous in Ba (2.4 per cent) and anomalous in Zn, Pb, Cu, Mo and Ag. A smithsonite(?) bearing barite-calcite vein is found cutting the sequence nearby.

Sulphide layers of similar composition and morphology are found within a dark slate, siltstone sequence with minor very fine grained sandstone on Horneline Creek, approximately 6 kilometres upstream from its confluence with the Kechika River. These horizons are only slightly anomalous in zinc and barium.

Rocks of the Kitza Creek facies in the Kitza Creek and Red River areas carry abundant sulphide vein mineralization and the area has been the subject of past exploration activities (*see* section on Veins; Miller and Harrison, 1981a, b, c). The origin and source of vein mineralization is not fully understood. Miller and Harrison (1981a) speculated that the numerous veins are probably dewatering structures as opposed to hydrothermal or intrusive-related. This is probably based on their simple mineralogy, lack of related alteration and no evidence of a nearby intrusion.

If these occurrences are truly dewatering features, then there were overall high levels of Zn, Ba, Ag, Pb and F in the enclosing sediments. No data exist on the background levels of these and other elements in Kitza Creek lithologies. A recent lake-sediment survey over the Kitza Creek area returned very anomalous values of Zn, Ba and other elements (Cook *et al.*, 1997). These values may simply reflect vein mineralization in these rocks, but the magnitude of some of the anomalous lake-sediment values (Zn - 5800 ppm; Cd - 39 ppm; Ni - 500 ppm; Ba - 2800 ppm; Mo - 55 ppm; Cook *et al.*, *ibid.*) suggests that there may be larger areas of mineralization. Clearly, this poorly exposed and underexplored region of favourable geology and anomalous geochemistry deserves greater attention.

MIDDLE TO LATE DEVONIAN

Middle to Late Devonian sedex sulphide deposits are by far the most numerous and economically important occurrences in the ancient western miogeocline. The number and size of known deposits of this age dwarf all other lower Paleozoic sedimentary exhalative showings (except for the Howards Pass area) and make the Earn Group one of the most important metallotects of the Canadian Cordillera. Although the eastward onlap of Earn clastics erased the previous boundaries of the Selwyn and Kechika basins along the ancient western miogeocline, important Late Devonian sedex mineralization occurred within the previous limits of these basins, suggesting that this region was still tectonically distinct from the eastern miogeocline. The eastern limit of the Kechika Trough would not re-establish itself until mid-Mississippian times and in a position much further to the east. Strata of Middle to Late Devonian age within the previous limits of Selwyn and Kechika basins offer the best potential for discovery of economically viable mineral deposits.

Devonian sedimentary exhalative mineralization is hosted by the Earn Group and can be subdivided into two main categories: Ba±Zn±Pb±Ag and Ni-Zn-PGE. Nickel-zinc-platinum group mineralization, has been recognized in only a few localities and only in very thin and, at present, uneconomic deposits. Barite±Zn±Pb±Ag occurrences, on the other hand, are numerous and suggest that the Earn Group holds the potential to contain other large, economically feasible deposits.

Nickel-Zinc-Platinum Group Elements (094L 018)

Stratiform Ni-Zn-PGE mineralization has only recently been recognized as a distinct deposit type. There are two well known deposits; one in southern China (Coveney *et al*, 1992) and one, the Nick deposit, in the Yukon (Hulbert *et al*, 1992). The following summary is taken from a paper by Hulbert *et al.* (*op. cit.*) which describes the characteristics of the Yukon occurrences. The "type locality" is within an outlier of Selwyn Basin stratigraphy along the edge of the MacDonald Platform, in north-central Yukon. Showings are at the base of the Earn Group, near its contact with calcareous rocks correlative with the Road River Group. Mineralization occurs at the base of a phosphatic chert member up to 8 metres thick, which overlies a distinctive limestone-ball unit, some 3 to 20 metres thick, which, in turn, is underlain by rocks transitional with the Road River Group. The exact age of mineralization is poorly constrained. Unpublished conodont collections from this stratigraphy (Geological Survey of Canada, Report Number OF - 1991-7) bracket mineralization between the Eifelian and Frasnian (early Middle to early Late Devonian). The limestone-ball member yielded Eifelian conodonts whereas latest Givetian to Frasnian conodonts were recovered from a unit 15 metres above the mineralized horizon. The mineralizing event is very likely Eifelian in age because Hulbert *et al.* (1992) argue that the limestone-ball member is a vent deposit that formed during sulphide deposition.

The mineralized horizon is thin, from 0.4 to 10 centimetres and, on average, carries of 5.3 per cent Ni (vaesite; NiS_2), 0.73 per cent Zn (sphalerite), 28.0 per cent sulphur and 776 ppb PGE (primarily Pd, Pt and Re) and Au. It is also anomalous in U, Mo, Ba, Se, As, V and P. Fresh surface samples of the mineralized horizon are difficult to find, but when available, contain of 40 to 65 per cent sulphides in the form of rhythmically laminated metalliferous sediments. In general, sulphides consist of pyrite (48 per cent), vaesite (10 per cent), sphalerite (2 per cent) together with gangue (39 per cent; phosphatic-carbonaceous chert, amorphous silica) and bitumen (1 per cent).

Although the mineralized unit is thin, it is laterally extensive, covering an area greater than 80 square kilometres. This, in combination with its relatively high grades, results in a nickel resource exceeding 900 000 tonnes (Hulbert *et al.*, 1992). As impressive as this appears, the difficulty of mining a gently to tightly folded and faulted ore horizon only several centimetres thick renders this deposit uneconomic.

As they point out, a sedimentary origin for this mineralization is demonstrated by its extensive, stratiform distribution, the rhythmically laminated character of the mineralization and the association with chemical sediments (phosphatic cherts). Furthermore, the limestone-ball member is considered to be an integral part of the deposit and probably formed close to vent areas. This is not a sedex deposit, *sensu stricto*, in that it did not form at the water-sediment interface. Rather, hot metalliferous brines and nutrients are believed to have migrated through seafloor oozes from the vent areas. This promoted organic activity, which led to sulphate reduction and sulphide precipitation.

High demand for nickel in the late 1980s saw a corresponding increase in exploration for this metal. This, in conjunction with the newly recognized Ni-Zn-PGE stratiform deposit on the Nick property, led to re-examination of the Kechika Trough for similar occurrences. Geochemical pulps, collected in the early 1980s during a regional geochemical survey of the Kechika Trough by Archer, Cathro and Associates Ltd. in the search for Zn-Pb-Ag sedex targets, were re-analyzed and a belt of anomalous zinc and nickel in soil and silt, 20 kilometres long was recognized and led to the acquisition of mineral claims in the Bluff Creek area (Carne and Parry, 1990; Carne, 1991). These anomalies, together with favourable stratigraphy, led Carne and Parry to suggest that they reflect stratiform Ni-Zn-PGE mineralization similar to the Nick property in the Selwyn Basin. This is supported by elevated levels of Zn, Ni, P, V, Mo, As, Cu, Co and Cd which are similar to anomalous metal concentrations related to the Nick mineralization.

The characteristic limestone-ball and phosphatic chert members seen at the Nick showing were not observed at exposed sections of the lowermost Earn Group in our study area. The closest lithologic correlative to this couplet would be the chert-limestone sequence mapped as part of the uppermost Road River Group, but conodonts from this limestone indicate that it is Emsian, slightly younger than Nick mineralization. No geochemical data from this study are available to indicate whether the chert-limestone marker is anomalous in the elements associated with Nick-style mineralization.

BARIUM±Zn±Pb±Ag

Numerous Late Devonian bedded barite occurrences, together with areas of anomalous lead and zinc were discovered between Gataga River and Horneline Creek by exploration activities in the 1970s and 1980s. Our work resulted in the discovery of many more occurrences and documented, for the first time, previously discovered but unreported showings (Figures 2 and 3). The number and thickness of these bedded barite occurrences clearly indicates the presence of hydrothermal activity in the northern part of the Kechika Trough during Late Devonian time. The future challenge is to determine whether these exhalative centres with barite and minor sulphides represent relatively low temperature systems, or if this extensive barite mineralization is distal to higher temperature vent systems containing significant concentrations of sulphides.

The following is a listing and brief description of known or probable Late Devonian sedex occurrences in the area. Some (*e.g.* Bluff Creek, Mat, Solo) have been known and described for several decades and are part of the extensive MINFILE database. Others (*e.g.* Broken Bit Barite, Term) have only been documented since the beginning of this mapping program.

The area was first systematically explored for sedex mineralization in the 1970s and early 1980s in response to similar newly discovered deposits in the MacMillan Pass area. Geologists, working in the Selwyn Basin, traced favourable stratigraphy and tectonic elements southward into the Kechika Trough. These efforts paid off with the discovery of the Cirque and Driftpile Creek deposits. This early exploration located many of the sedex occurrences now documented in the Kechika Trough; more recent efforts led to discovery of others, like the Akie deposit. New showings found during this mapping program, and by exploration companies working in the map area, indicates that there is still potential for discoveries within this relatively underexplored sedex metallogenic province.

Bluff Creek (094L 018)

The Bluff Creek Ba-Zn showing was originally discovered in 1977 by Texasgulf Canada Ltd. Sampling of calcrete deposits along north side of Bluff Creek returned zinc values as high as 8.4 per cent as well as anomalous lead and copper (Boyle, 1978a). Noranda Exploration Co. Ltd. staked the ground surrounding the Bluff Creek claims, on the basis of anomalous zinc in stream sediments, zinc-oxide coatings on Earn(?) rocks and the presence of bedded barite (MacArthur, 1981a). Further work by Noranda narrowed efforts to an area on the south side of Bluff Creek which contained numerous ferricrete occurrences and anomalous zinc, copper, molybdenum and silver in soils (MacArthur, 1982). Both companies dropped their claims due to lack of coincident lead and zinc anomalies. The area was restaked by NDU Resources Ltd., and later acquired by Falconbridge Ltd. because nickel values associated with these occurrences suggested the potential for Nick-style Ni-Zn sedex mineralization (Carne, 1991; Parry and Carne, 1990; *see* section above).

No bedded sulphides are documented for this showing. The occurrence consists essentially of a ferricrete dep[illegible]n the north side of Bluff Creek which has reported zinc values ranging form 4 to 8.4 per cent (Boyle, 1978a). It occurs above shales and siliceous argillites of the Earn Group which extend on either side of the creek (Figure 24). Boyle also notes that grab samples of nearby Earn lithologies returned zinc values as high as 3900 ppm.

Soil sampling south of Bluff Creek returned zinc values as high as 9000 ppm (MacArthur, 1982) In addition, copper, silver and molybdenum are also anomalous. MacArthur (1982), and geologists with the B.C. Geological Survey Branch, noted the presence of numerous ferricrete occurrences within Earn lithologies elsewhere in this area.

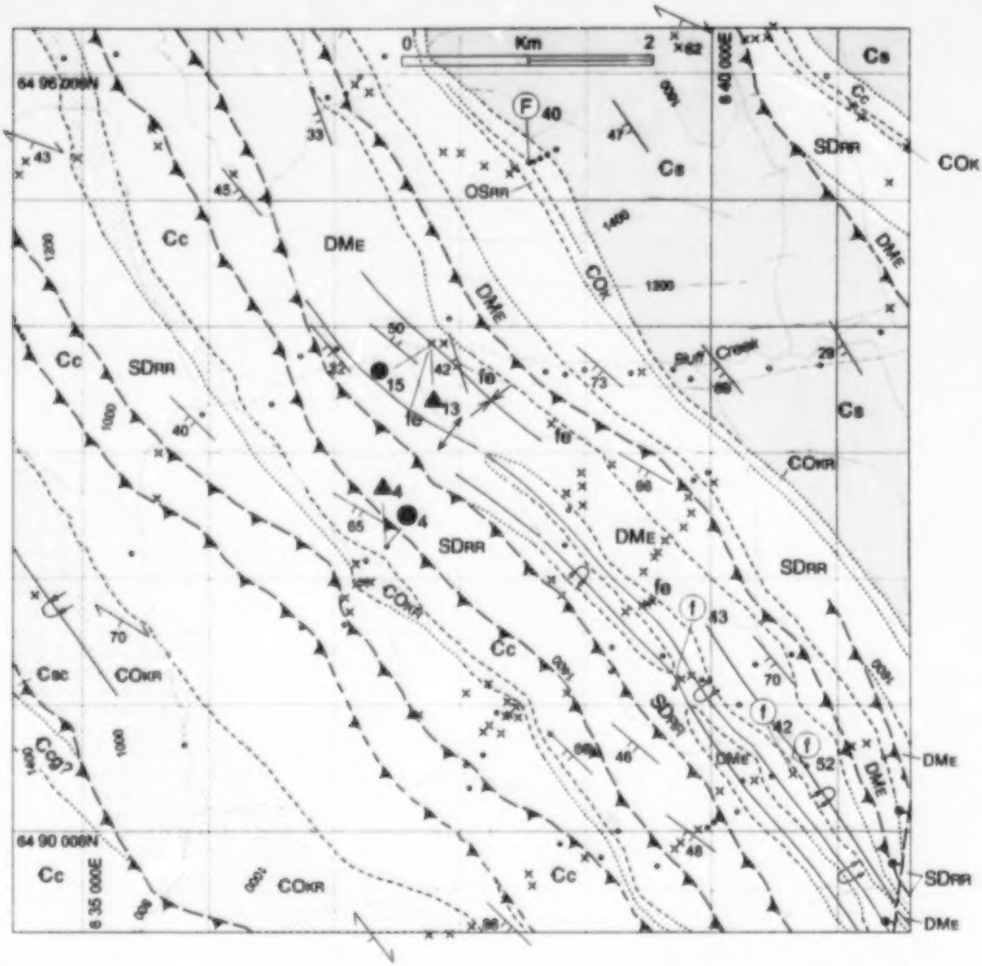


Figure 24. Geology around the Bluff Creek Minfile occurrence (locality 15) which consists of a Zn and Ni-rich ferricrete deposit. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

Solo (094L 015)

The area around the Solo showing was first examined in 1978 by TexasGulf Canada Ltd. in response to anomalous results from stream sediment samples collected in 1977 (Boyle, 1978b). The area lies approximately 5 kilometres west of the southern end of Netson Lake (Figure 25). No mineralization was discovered by this follow-up work, although the anomalous stream sediment values were reproduced and traced to white tuffa or calcrete deposits along the creek (Boyle, *op. cit.*).

The location of the Solo occurrence described in the Minfile database is centered on stratiform barite showings just south of the original Solo mineral claims reported on by Boyle (1978b). The name of the original claims was used to designate the occurrence, in order to tie the two anomalous locations together and to suggest the potential for more substantial sedex mineralization. It is interesting to note that our mapping located eight more sites of either bedded barite or ferricrete with anomalous metals values on or immediately adjacent to the original Solo mineral claims (*see* Figure 25; Tables 4a and 5a).

The Solo barite and ferricrete occurrences are on strike and within the same panel of Earn rocks as the Bluff Creek showing. Black slate of the Earn Group contains a 1-metre thick section with blebs of barite from 0.1 to 0.5 centimetre in diameter comprising up to 30 per cent of the unit. Layers with coarse crystalline to finely laminated pyrite are found with this barite and constitute up to 10 per cent of the sequence. Analysis shows 10.6 and 4.4 per cent barium and iron, respectively, but only background levels of lead, zinc and silver.

Six occurrences of bedded or blebby barite are located approximately 3.5 kilometres northwest of the Solo site, primarily along a northwest-flowing creek. They consist of bedded barite, from 10 centimetres to 2 metres in thickness, within siltstone and mudstone of the Earn Group. At locality 22, bedded barite is exposed in up to four horizons, one being 2 metres thick. Several of these barite layers are char-

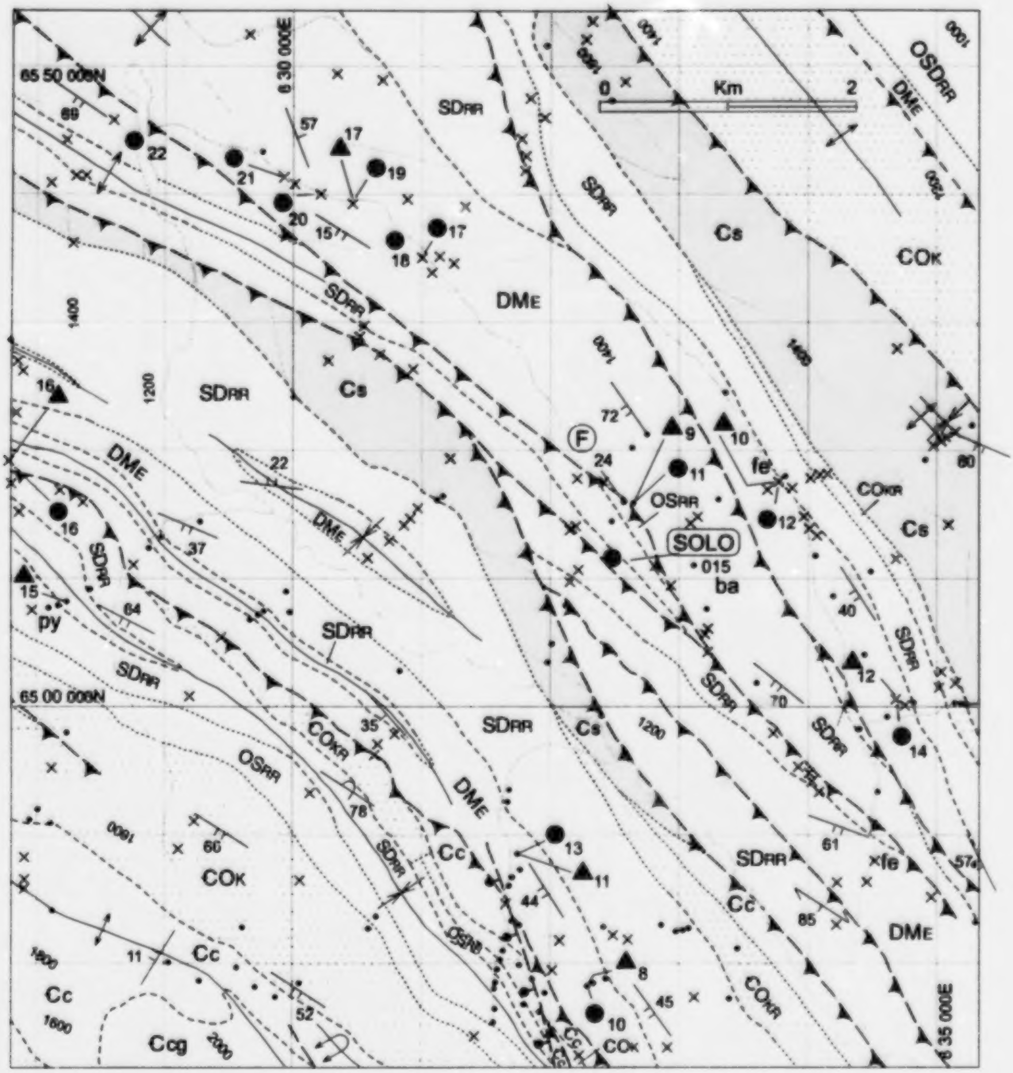


Figure 25. Geology and mineral occurrences in the vicinity of the Solo Minfile showing. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

acterized by small nodules or lenses of black chert (Photo 71). Some pinch out over the 100 metre length of the outcrop. An analysis from one horizon returned anomalous levels of zinc (212 ppm) and lead (30 ppm) together with 0.6 per cent barium. Considering the surface area covered by the Earn Group in this area, at least some of these sections are probably repeated by folding and/or faulting.

Cominco Exploration Ltd. staked the ground around the creek immediately north of these occurrences to cover an area of anomalous Zn values correlating with an anomalous stream sediment sample from the 1996 RGS survey (Wagner, 1997a; Jackaman *et al.* 1996). Prospecting led to the discovery of another massive to semimassive barite horizon, 1.2 metres thick, that carries zinc values up to 201 ppm (Wagner, *op. cit.*).

Broken Bit Barite (094L 024)

Another 5 kilometres northwest of the half dozen barite occurrences associated with the Solo occurrence is a large area, some 50 by 70 metres in size, that is devoid of vegetation and underlain by rubble of massive calcareous barite, some paler grey baritic limestone (witherite?) and a lesser amount of blue-grey-weathering siliceous slate (Figure 26, Photos 72, 73 and 74). This locality was first reported by geologists with the B.C. Geological Survey Branch (Ferri *et al.*, 1996a, b) and later examined in greater detail by Cominco Exploration Ltd. as part of a larger claim block encompassing disseminated lead-zinc mineralization 5 kilometres to the northwest (Wagner, 1997b). The name is taken from that of an outfitters camp located a few kilometres to the west.

Photo 71. Massive bedded barite/witherite, containing characteristic black, cherty nodules, hosted by the Earn Group in the vicinity of the Mat occurrence.

The largest block of barite is 30 centimetres across and crudely layered (Photo 74). The nearest bedrock outcrop is black slate of the Earn Group in the creek immediately to the southwest. Few sulphides were noted and this was substantiated by later geochemical sampling (Wagner, 1997b; Table 5a). A sample of calcareous barite assayed 41.46 per cent barium; more limy material contains about half this amount. Coarse, granular 'sand' below the rubble contains 47.91 per cent barium, accounting for the lack of vegetation and even lichen. A small creek gully, 500 metres along strike to the southeast of the kill zone, contains rubble of grey calcareous barite to baritic limestone, suggesting that the barite horizon extends at least that far.

Work by Cominco located a zone of pyritic Earn shale at the southern end of the property (Figure 26). It is reported to measure some 50 by 150 metres and is composed of up to 5 per cent finely crystalline disseminated pyrite in black siliceous shale (Wagner, 1977b). Abundant pyrite is rare in Earn rocks and its origin may be related to sedex processes.

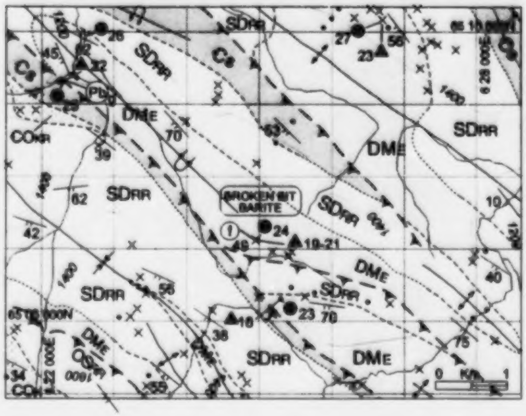


Figure 26. Geology and mineral occurrences in the area around the Broken Bit Barite showing. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

Sampling and analysis of this pyrite-rich zone showed background levels of lead and zinc.

Wagner (1997b) also reported the presence of a zinc-rich (up to 5.7 per cent) calcrete deposit along the southern end of a thrust fault immediately south of the Broken Bit Barite showing. The zinc deposit is believed to have been leached from Earn lithologies and the thrust fault to have acted as a fluid conduit (Wagner, *op. cit.*).

Mat (094 019)

In 1979, Esso Minerals Canada staked the Mat mineral claims, approximately 5 kilometres northwest of Netson Lake, to cover ferricrete deposits in soils and massively bedded barite showings (Figure 27, Stewart, 1980). Stewart (*op. cit.*) reported the existence of an earlier grid indicating the showing was previously explored but not reported. Esso Minerals established a new grid over the property and systematically collected soil samples which were analyzed for copper, lead, zinc and silver. Zinc-copper anomalies were delineated, but no coincident high levels of lead. The anomalies were interpreted as due to calcrete deposits resulting from fluid-flow along fault systems, no further work was recommended and the claims were dropped.

Our mapping along the main ridge within the original Mat claims encountered several horizons of bedded to blebby barite (Figure 27; Photo 75; Tables 4a and 5a). Grey to dark grey weathering and calcareous barite beds range from 5 to 200 centimetres thick. The bedded barite weathers like limestone, suggesting a high calcium content and that much of the barium may be present as witherite. Some of the thicker horizons have small, dark grey to black cherty nodules typical of other Earn-hosted barite occurrences. Barite horizons are found with dark grey to blue-grey weathering, dark grey carbonaceous siltstone to slaty siltstone. Analyses of samples from these horizons returned between 43.4 and 36.6 per cent barium and negligible levels of zinc, lead, although silver levels are elevated.

Nodular barite is present sporadically in a section of dark grey to black fissile slate, some 20 metres thick, exposed along the ridge. Nodules of radiating barite crystals, 1

Photo 72. Aerial view of the 'kill zone' associated with Broken Bit Barite occurrence.

Photo 73. Surface view of the Broken Bit Barite 'kill zone'.

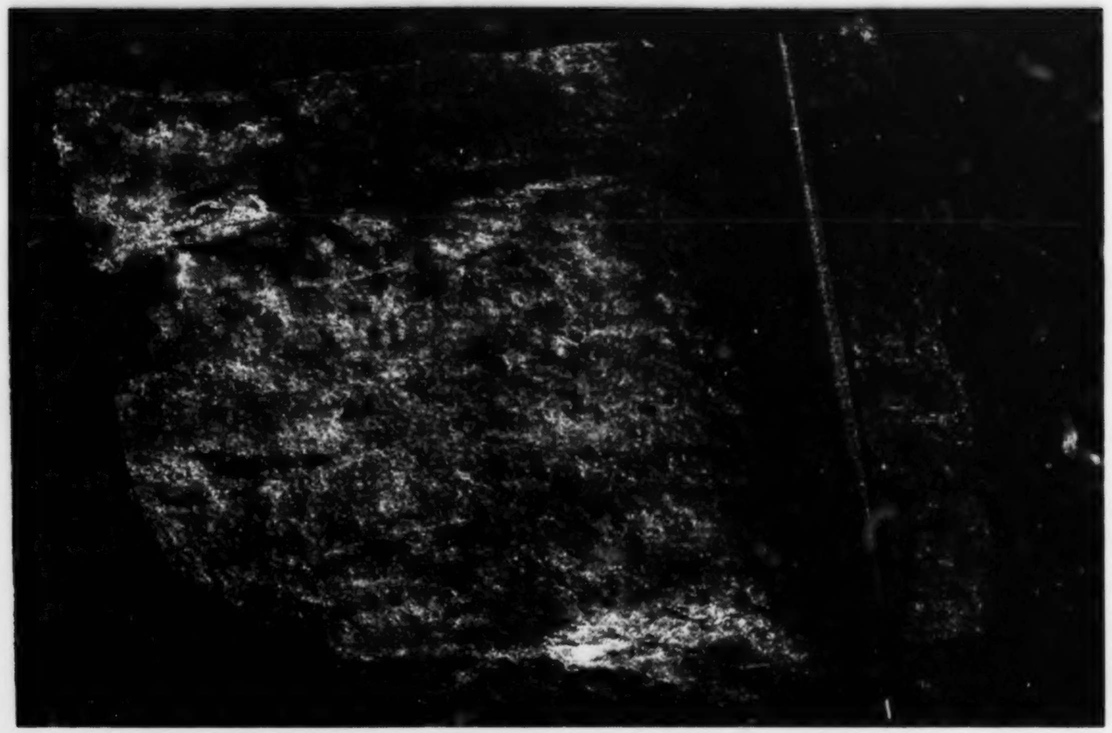


Photo 74. Crudely layered barite/witherite in a talus block from the 'kill zone' at the Broken Bit Barite occurrence.

to 5 centimetres long, comprise up to 30 per cent of individual beds 5 to 20 centimetre thick.

Several other barite±sulphide occurrences are located near the Mat showings. Approximately 3 kilometres to the northwest is a section of dark grey to black carbonaceous siltstone and slate with up to six layers of orange-weathering barite 3 to 10 centimetres thick. Disseminated pyrite and authigenic barite crystals up to 5 millimetres long are found in some of the barite beds. One of the thicker layers sits above fetid slate with abundant disseminated pyrite. A sample of this pyritiferous slate and succeeding barite assayed 1.1 per cent barium and 4.8 per cent iron, but negligible lead, zinc and silver. These baritic horizons crop out approximately 5 metres above the contact with the Road River Group and can be traced for about 100 metres. Some of the barite layers grade laterally into nodular barite.

About 2 kilometres further north, on the other side of a broad syncline, another occurrence of bedded barite is exposed at roughly the same stratigraphic horizon. It consists of approximately 2 metres of dark blue-grey limestone and calcareous barite (witherite?) with partings of chert and cherty siltstone. Baritic zones contain chert nodules from 2 to 10 millimetres in diameter and tiny authigenic barite crystals. A conodont sample from the limestone contained elements suggesting a Middle to Late Devonian age.

A thin barite layer in a mudstone-radiolarian chert sequence of the Earn Group is exposed immediately to the southwest, in the next syncline.

Chief (094L 038; 094L 039)

Mapping by the B.C. Geological Survey Branch in 1995 led to the discovery of multiple horizons of bedded barite in Earn rocks some 12 kilometres northeast of Terminus Mountain (Figure 28; Photo 76; Tables 4a and 5a; Ferri *et al.*, 1996a, b). As a result, Cominco Exploration Ltd. initially staked six two-post claims over these showings and later added additional claims to the west, when silt samples from creeks returned strongly anomalous zinc values (Wagner, 1997c). Although the 1996 Open File and related Geological Fieldwork article were the first to document this occurrence, field observation suggested previous sampling and a search of the records at the Mineral Titles Branch revealed that these showings were in the abandoned Magnum claim group recorded in the early 1980s and dropped without submitting any assessment work.

Subsequent work by Cominco defined three styles of mineralization within Earn rocks: semimassive to massive, bedded barite; disseminated pyrite in siliceous shales; and a crosscutting sphalerite-bearing calcite-barite-limonite-quartz breccia unit (Wagner, 1997c). Bedded barite is exposed at two and possibly three horizons. Dark grey to almost black, fetid calcareous barite is interlayered with dark grey cherty argillite in a section approximately 1.5

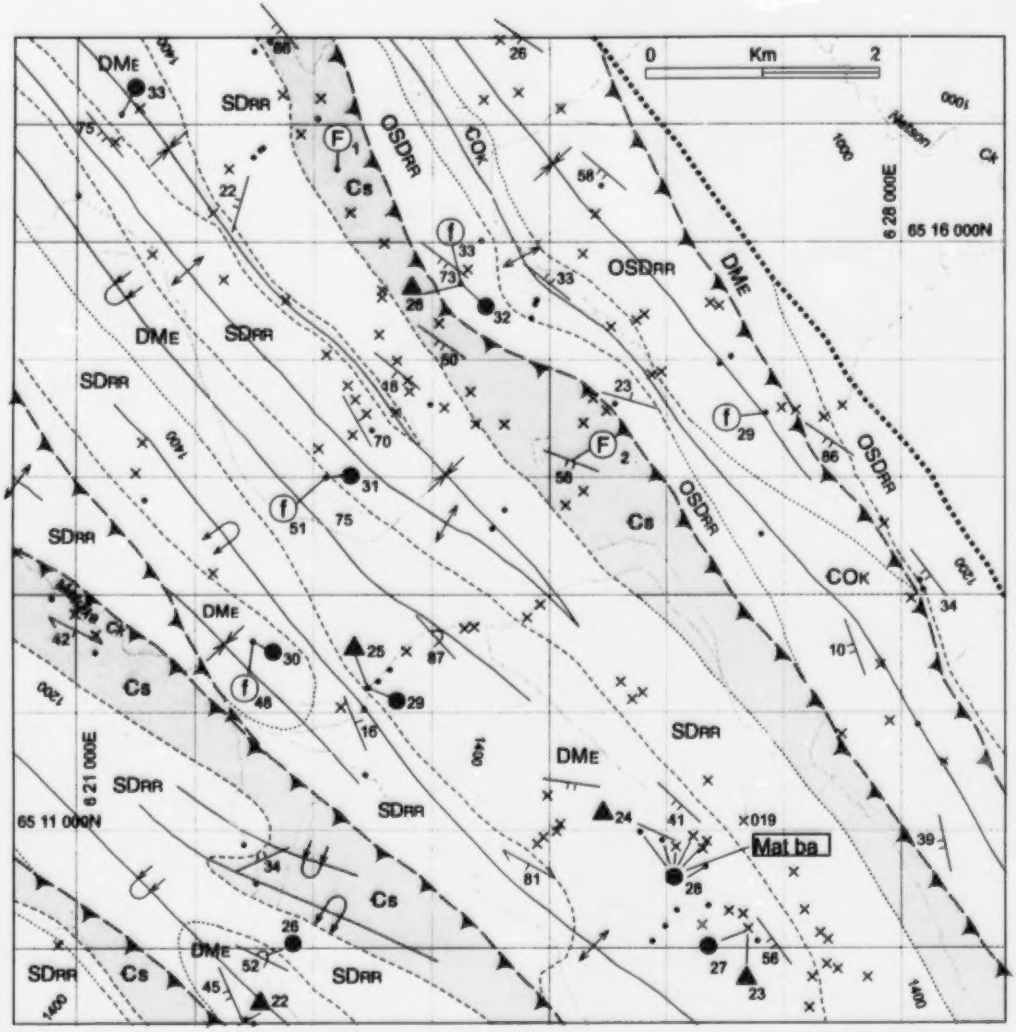


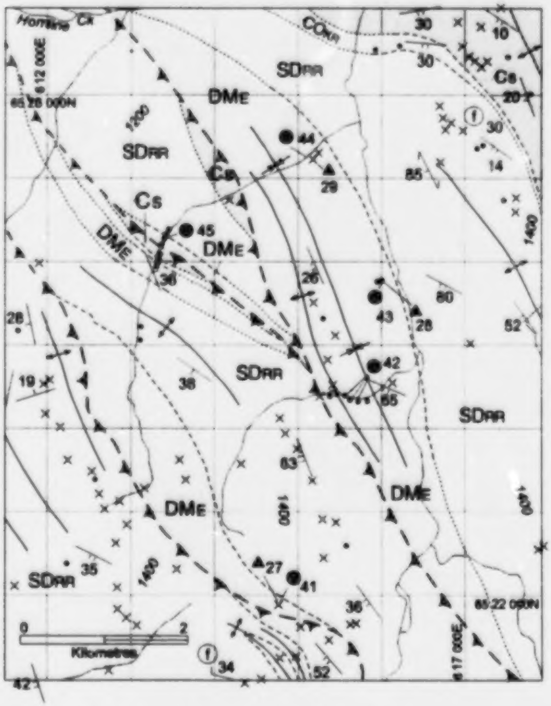
Figure 27. Geoogy in the area around the Mat showing, and other nearby mineral occurrences. Symbols, linetypes, *etc*. Are identical to those on Figures 2 and 3.

metres thick, 1 kilometre north of the Chief showing (Figure 28). This barite is interpreted to occur close to the Earn - Road River contact. Analysis indicates 48.34 per cent barium and low base metal values (Table 5a). Further south, and apparently up section, several occurrences of massive, bedded barite are believed to be repetitions of the same horizon (Chief showing). This barite is up to 2 metres thick, grey weathering, massive or with poor flaggy partings and found within dark grey to black fissile slate and argillite. Wagner (1997c) reports a 30 by 5-metre kill zone 150 metres to the northwest, containing blocks of massive barite (Brave showing). Both the Brave and Chief showings contain low base metal values. There are two other occurrences of barite in this area mentioned by Wagner (*op. cit.*), one of which was relocated during this project. Both consist of fine (1-2 mm), elongate crystals of barite set in a soft, grey-brown to green-grey, thin-bedded or fissile siltstone which may be sericitic. Wagner suggests these sericitic horizons have a volcanic origin. Sampling of one horizon returned 7.22 per cent barium and 2050 ppm zinc (Wagner, 1997c).

Earn shales at the north end of the claim block contain several per cent disseminated pyrite. Analysis of several horizons by this project and Cominco Exploration Ltd. returned negligible base metal values (Table 5a; Wagner, 1997c).

The third type of mineralization is exposed approximately 5 metres east of the Chief barite occurrence. It consists of a breccia zone, 3 metres wide which crosscuts rusty slate below bedded barite (Wagner, 1997c). Breccia is composed of angular clasts of siliceous shale in a matrix of calcite, barite, limonite, quartz and minor yellow-brown

Photo 75. Massive to bedded barite/witherite in the vicinity of the Mat occurrence.


Hominy Ck
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Kilometres
65 22 000N
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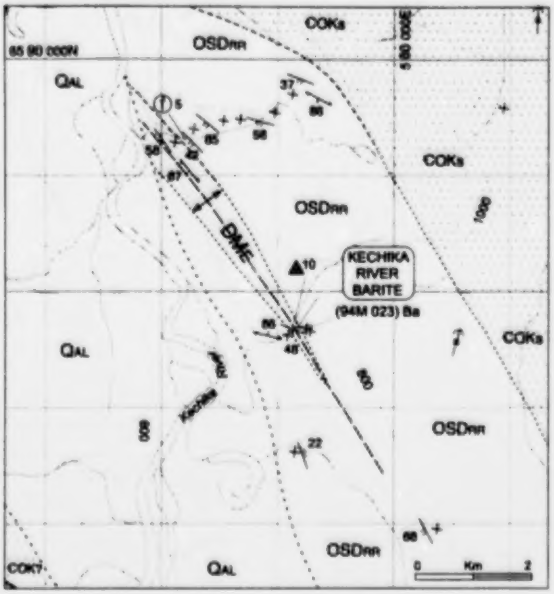
Figure 28. Geology in the area around the Chief mineral showing (locality 42). Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

Photo 76. Two-metre section of massively bedded barite/witherite in the area of Chief mineral occurrence.


COKs
65 90 000N
OSDRR
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QAL
COKs
OSDRR
DME
KECHIKA
RIVER
BARITE
(94M 023) Ba
QAL
COKs
OSDRR
OSDRR
COK?
QAL
0
Km
2

Figure 29. Geology in the area around the Kechika River barite showing. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

sphalerite. Sampling of this breccia zone returned anomalous zinc (5800 ppm), copper (586 ppm) and 1.4 per cent barium (Wagner, *op. cit.*).

No other base metal anomalies are known to be associated with these occurrences. Although the main tributaries draining the properties have regionally anomalous zinc and barium levels (Wagner, 1997c), no primary base metal mineralization could be located as a possible source. The only locality with high base metal values is a calcrete deposit within Road River rocks, upstream from the Chief showing, containing 1.23 per cent zinc (Wagner, 1997c). This occurrence is not considered significant by Cominco Exploration Ltd. and is attributed to leaching and redeposition of metals from lithologies with high zinc backgrounds (Earn Group) and not to nearby mineralization.

Kechika River Barite (094M 023)

A new Earn-hosted barite-pyrite stratiform deposit was discovered during mapping in 1996. It is located along a creek valley approximately 9 kilometres northwest of Gemini Lakes and 1 kilometre upstream from the creek's confluence with the Kechika River (Figure 29; Photo 77; Table 4b).

The bedded barite sequence is at least 4 metres thick, and its base is not exposed. Parts of the outcrop weathers a bright orange colour due to oxidation of iron sulphides. Individual barite beds are 1 to 10 centimetres thick and comprise approximately 30 per cent of the section (Photo 77). A pale coloured, well cleaved rock, of unknown composition, is interlayered with the barite. It may be either altered slate or possibly fine-grained felsic tuff. Barite is fine to medium grained and contains fine pyrite laminations or tiny orange

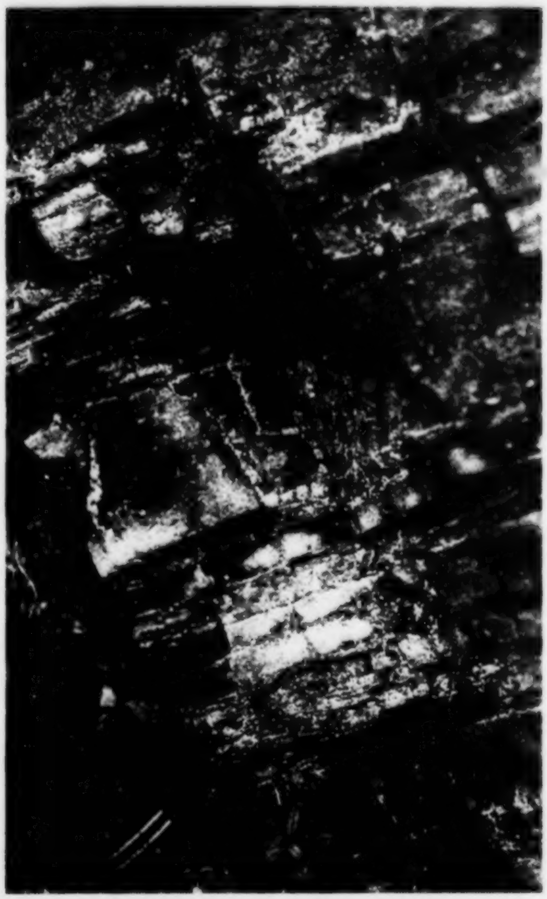
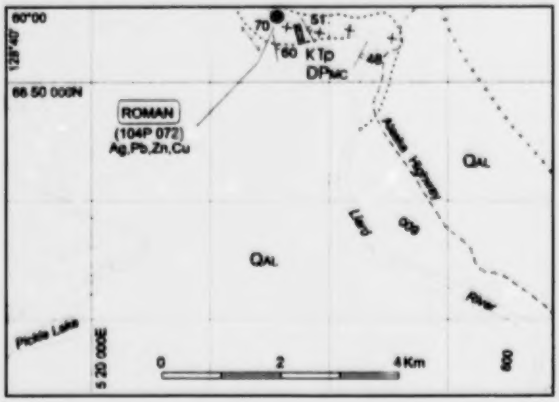


Photo 77. Bedded barite/witherite typical of Kechika River Barite occurrence.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128°40'
66 50 000N
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(104P 072)
Ag,Pb,Zn,Cu
KTp
DPMC
QAL
Alaska Highway
Liard
QAL
River
Pickle Lake
5 20 000E
0
2
4 Km

Figure 30. Geology in the area around the Roman occurrence. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

spots which may be limonite after sulphides. Locally, pyrite is also finely disseminated within the layers. The barite sequence is overlain by medium to dark grey slate with flattened pyrite concretions, horizons of barite nodules and finely laminated pyrite.

A grab sample from this barite-rich zone returned 42.5 per cent barium and low levels of base and precious metals (198, 6, 17 and less than 0.3 ppm zinc, lead, copper and silver respectively; Table 5b). If the pyrite in this sequence is a product of sedex processes, then proximity to the vent area is suggested and there is potential for higher concentrations of base and precious metals nearby. A multi-element stream sediment sample was collected from the mouth of a creek three kilometres to the north and cutting the Earn Group rocks on strike with those hosting the Kechika River Barite occurrence. This sample (FF96-006; Cook *et al.*, 1997) contained elevated levels of Ba, As, Cd, Mo, Ni, Pb, Sb, Zn and Ag.

Roman (104P 072)

Sulphide mineralization of stratiform character is exposed at the Roman showing (MINFILE occurrence 104P 072), along the lowest part of the Liard River within the study area (Figure 30). The occurrence is associated with numerous sulphide-rich veins that are described below. The main showing outcrops along the north bank of the Liard River less than kilometre south of the British Columbia - Yukon border. A smaller barite showing, possibly related to this occurrence, is exposed along the south bank of the Liard River some 8 kilometres to the northwest. The Roman prospect was first staked in the early 1960s, worked intermittently until the late 1980s (Cukor, 1981; Rainsford, 1984; and Mark, 1988) and again more recently (Chow and Barrie, 1997). A more detailed account of the early exploration history of this property is provided by Rainsford (1984).

The main showing was not visited by the authors; the following account is taken from Mark (1988) and Rainsford (1984). The showing is hosted by black graphitic slate and thin to moderately laminated, dark grey silty limestone of the Earn Group. Carbonaceous sandstone to quartzite is exposed above the sulphide-bearing horizon. Several concordant to discordant sphalerite and galena bands or lenses, up to 20 centimetres thick, can be traced for 10 metres before they disappear under the Liard River. Fine pyrite laminations and barite lenses are described from a related site across the Yukon border. Reported assays of the sulphide lenses at the main showing are 22.6 per cent zinc, 46.3 per cent lead and 23 grams per tonne silver (Mark, 1988). The contact zone between carbonaceous slates and quartzites exhibits a pervasive muscovite-sericite alteration and bleaching, and there are numerous quartz veins cutting the silicified zone. Patches of galena, sphalerite and tetrahedrite are present within the silicified zone. Rainsford (1984) suggests these features are part of a sedimentary exhalative feeder system, although our observations of the vein system on the north side of the river suggest that it is much younger, and related to regional folding (*see* below). This does not rule out the possibility that some of the veins may indeed represent a syn-sedimentary feeder system.

On the opposite side of the river, rocks very similar to those at the main showing are overlain by well-bedded and thinly interlayered pale salmon and green chert with thin pale green argillite partings. This unit is very similar to a Mississippian to Permian chert unit which overlies the Earn Group in the Cassiar Mountains and has been grouped with the Mount Christie Formation (Nelson and Bradford, 1993). There is a small outcrop of orange-weathering, carbonate-altered feldspar porphyry immediately east of the main showing. Further east, dark grey to orange-weathering, finely planar to crosslaminated micaceous sandstone and argillite are exposed. The sandstone is bioturbated with bedding-parallel worm burrows. The exact age of these rocks is unknown. Their dip is the same as the section at the main showing, suggesting that they lie stratigraphically above it. This would make them younger than Permian, if the correlation of the cherts with those in the Cassiar Mountains is correct, and possibly Triassic. Unfortunately the contact between these two sections is covered, allowing the possibility that the coarser clastics represent a thrust panel of older rocks, perhaps of Cambrian or Silurian age.

The West showing, across the border in the Yukon, consists of carbonaceous black shale with calcareous and siliceous intervals and thin carbonaceous sandstone layers (Mark, 1988). A conformable barite lens, 2 metres wide, together with numerous crosscutting and concordant barite-quartz veins is exposed within this sequence. Mark (*op. cit.*) reports that base and precious metal mineralization is associated with both styles of barite. He also notes the presence of bedded pyrite layers within a carbonaceous black shale sequence that is over 20 metres thick. The association of both bedded barite and pyrite at the West showing suggests that this mineralization may be related to sedex processes (Mark, 1988).

Term (094L 035; 094L 036)

Bedded barite mineralization, exposed several kilometres north of Terminus Mountain, was first documented by geologists with the B.C. Geological Survey Branch (Figure 31; Ferri *et al.*, 1996a, b). As a consequence, Cominco Exploration Ltd. carried out follow-up work and later staked a small area between several of these barite occurrences. The claims covered a watershed from which heavy mineral separates returned anomalous zinc and barite (Wagner, 1997d). The property was later surrounded by a large claim block, encompassing all the known showings, in response to very high zinc values obtained in both silt and soil samples.

There is some uncertainty surrounding the age of the rocks hosting mineralization at the Term property. Our mapping shows that these rocks are part of the Earn Group. Cominco geologists suggested that these shaly, carbonaceous lithologies are part of the Lower Road River Group and thus Ordovician to Early Silurian. There are few diagnostic fossil localities within this sequence. One conodont collection made by the B.C. Geological Survey Branch was inconclusive, showing only a broad Silurian to Triassic age range. A radiolarian collection made by Cominco, very near mineral locality 37, is Late Silurian to Devonian in age (D. Wagner, personal communication, 1998). The upper age range of the Lower Road River Group within the map area is

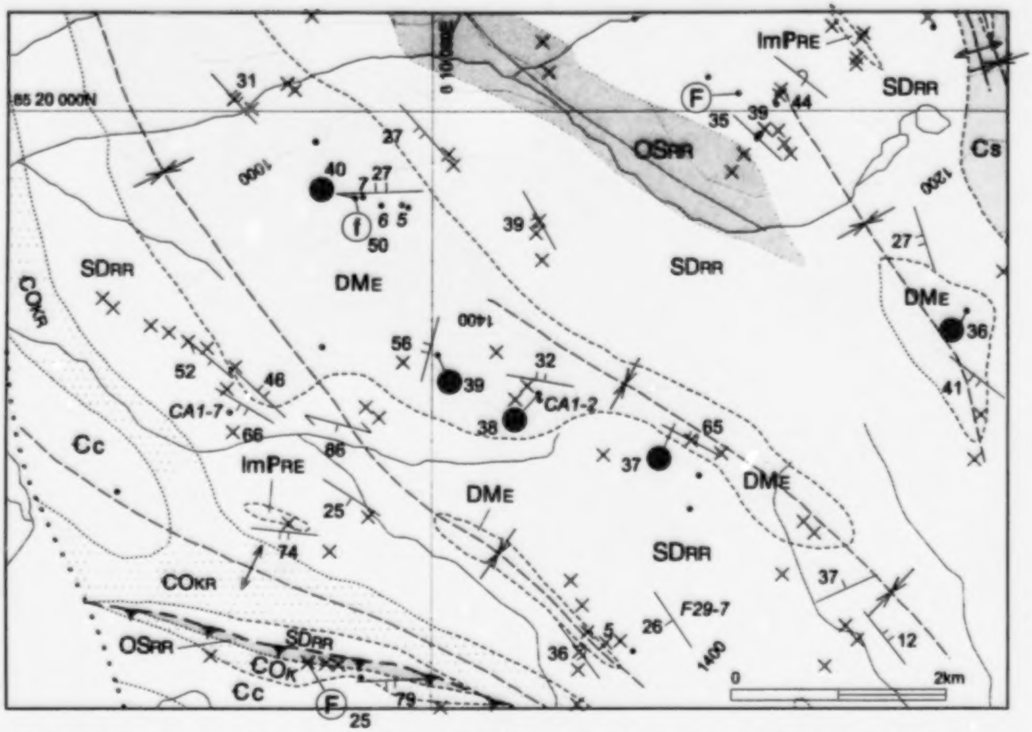


Figure 31. Geology around the barite occurrences (localities 37 to 39) in the area of the Term mineral claims (not shown). Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

late Early Silurian indicating that mineralized rocks at the Term property are probably part of the Earn Group.

Cominco geologists have provided a more detailed description of the host stratigraphy. There are three main units: a lower succession, up to 70 metres thick, of massive, rusty weathering, siliceous, black carbonaceous shale with white-weathering lensoidal to nodular chert; a middle, recessive section of up to 100 metres of black fissile shale with baritic limestone lenses or beds, which is succeeded by up to 15 metres of massive, siliceous black shale, also with baritic limestone lenses (Wagner, 1997d). Except for the presence of white chert nodules in the lower most part of the section, the remaining lithologies are entirely consistent with those of the Earn Group elsewhere within the map area.

Lenses to semicontinuous beds of light grey weathering, dark, fetid barite to calcareous barite were seen at various levels within the upper part of the sequence. They are from 0.5 to 7 metres thick, recrystallized, and characterized by nodules to lenses of black chert up to 0.5 centimetre across, which roughly delineate bedding. Similar nodules were described from baritic horizons in the vicinity of the Solo mineral showings (Photo 71).

No sulphide mineralization has been reported from the claim group. Geochemical analysis of several baritic horizons by Cominco Exploration Ltd. shows up to 3360 ppm zinc (Wagner, 1997d). Soil and stream sediment geochemical surveys indicate zinc values as high as 10500 and 15600 ppm respectively, with soil anomalies traceable for up to 600 metres (Wagner, *op. cit.*). Elevated zinc in soils is also associated with anomalous levels of copper and silver.

BRECCIA RELATED MINERALIZATION

Two occurrences of sphalerite-barite breccia are known within rocks of the Road River and Earn groups. One of these is associated with sedex mineralization in the area of the Chief showing and was described previously in the section on sedimentary exhalative (Sedex) mineralization. The other occurrence is in rocks of the Road River Group northeast of Terminus Mountain.

SMOKE (094L 016)

The Smoke mineral showing was first investigated by Noranda Exploration Company Ltd. in 1980 (MacArthur, 1981b). Noranda conducted a soil survey in the area around the breccia, but this work did not outline any other targets. The showing was visited and described by B.C. Geological Survey Branch geologists during the 1995 field season (Ferri *et al.*, 1996a, b). Cominco Exploration Ltd. subsequently staked a small claim block covering the occurrence and conducted a modest mapping and prospecting program (Wagner, 1997e). The following description is taken from Ferri *et al.* (1996a), augmented with information from Wagner (1997e).

A sphalerite-barite-rich breccia zone crosscuts chert, cherty argillite and argillaceous limestone of the Road River Group near the top of a ridge approximately 13 kilometres

Photo 78. Close-up of Ba-Zn-rich breccia horizon at the Smoke occurrence.

north of Terminus Mountain (Figure 23; Photo78). The ridge is dominated by lithologies of the Silurian siltstone unit and believed to be part of the same succession. The breccia zone is marked by gossanous pyrite-rich sections. It is about 10 metres long and varies from less than 0.5 metre to over 3 metres in thickness, before disappearing below scree. Its geometry is difficult to determine, but it appears to have a pipe-like shape which pinches and swells along its trace. Breccia clasts vary from less than 0.1 centimetre to over 20 centimetres across, and are composed of chert, limestone and argillite. The matrix is predominant, and is composed of rusty iron carbonate, calcite and barite. Pyrite is finely disseminated in the matrix and clasts. No sphalerite is visible in hand sample, but the breccia reacts strongly to diethylaniline stain ('zinc zap') and red-brown sphalerite is visible under a microscope. Selected grab samples from the breccia assay up to 3.4 per cent zinc, 9.1 grams per tonne silver and 1.0 per cent barium (Table 5a), in the same range reported by Wagner (1997e).

Wagner (*ibid.*) points out that that the eastern part of the breccia zone appears to be stratabound and is surrounded by deeply weathered, limonitic shale. We sampled this oxidized material and obtained only 0.2 per cent zinc, 1.1 grams per tonne silver and 2.1 per cent barium, again similar to results obtained by Cominco. These two areas appear to be anomalous with respect to Cu, Cd, Mo and Sb.

The shape of the breccia zone, and the absence of shear fractures within it or in hostrocks argues against a tectonic control. The simple mineralogy argues against a direct igneous origin. The simplest explanation for this occurrence is that it represents a collapse or solution breccia, although carbonate is not abundant in the sequence. Considering the location of this breccia within a sedex metallogenic province, it is tempting to suggest that it represents a hydrothermal conduit which may have formed exhalites at surface. The presence of iron-carbonate in the matrix, which is a typical alteration mineral associated with Earn-hosted sedex occurrences, together with sphalerite, barite and pyrite is compatible with this. In this model, the low concentration of pyrite, the absence of pyrrhotite and galena, together with the barite-sphalerite mineral assemblage and the restricted nature of alteration all would suggest a low temperature system. The closest known occurrence of sedex mineralization is a few kilometres to the northeast but is Silurian (Early?) in age, apparently older than lithologies hosting the breccia zone.

TUNGSTEN - MOLYBDENUM PORPHYRY/SKARN (BOYA MAIN FACE 094M 016 AND BOYA WEST HILL 094M 021)

Mineralization along the ridge informally referred to as 'Boya Hill' was first discovered in the late 1970s by Texas Gulf Canada Ltd. (later Kidd Creek Mines Ltd.) during a regional exploration program that targeted sedimentary exhalative deposits in the northern Kechika Trough (Figure 32). The area was initially staked as a raw tungsten prospect with mineralization hosted by skarn and quartz veins associated with granitic intrusions (Peatfield *et al.*, 1978). Subsequent exploration indicated the significance of molybdenum mineralization in the intrusion-related stockwork system (Peatfield, 1979a). Encouraging initial results led to an intensified exploration program, further ground acquisition and approximately 3950 metres of diamond drilling in 16 holes (Peatfield, 1979a, b, c; 1980a, b, c; 1981a, b; Moreton, 1984). Initial drilling indicated low grades but several promising targets encouraged further exploration. These were followed up but found to be cut off at depth by a gently dipping thrust fault. The property was dropped after deep exploratory drilling failed to locate further mineralization below the thrust fault, indicating that the deposit, if it existed, lay several kilometres to the west, in the footwall of this thrust.

The western part of Boya Hill, encompassing the Boya West Hill showing, has recently been staked by Tizard Exploration Ltd. Exploration activity consisted of an airborne magnetic survey, soil sampling and ground geophysics.

This deposit has been catalogued as two distinct occurrences in the Minfile database: Boya Main Face (094M 016) and Boya West Hill (094M 021). The following description

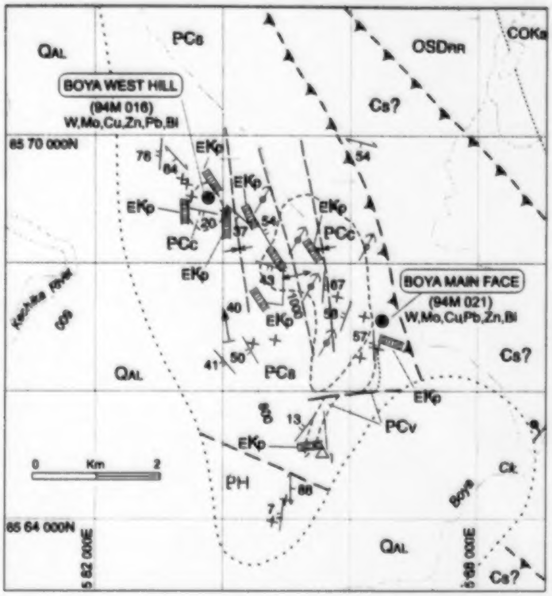


Figure 32. General geology around Boya Hill showing the location of the Boya Main Face and Boya West Hill occurrences. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.

will not adhere to this scheme but instead will summarize the various characteristics of mineralization. This synopsis is condensed, for the most part, from a detailed examination of mineralization along Boya Hill carried out by Moreton (1984) as part of an M. Sc. thesis.

Mineralization on Boya Hill is classified as a W-Mo stockwork-skarn (Moreton, 1984; Dawson, 1996; Sinclair, 1986; 1996). Canadian Cordilleran examples of deposits of this type include Logtung, Yukon (Noble *et al.*, 1986; 1996) and the Mount Reed - Mount Haskin deposits in northern British Columbia (Gower *et. al.*, 1985). In these deposits, porphyritic intrusive rocks and, to a lesser extent, adjacent hornfels and skarns, contain Mo and Mo-W-bearing quartz-vein stockworks. The stockwork system is associated with alteration assemblages typical of porphyry deposits. Generally, the stockwork is molybdenum-rich within the intrusive phases and the concentration of tungsten increases towards the porphyry contact and into the surrounding hornfels or skarn. Tungsten-rich mineralization is most abundant in skarn peripheral to the porphyry. These deposits are also associated with late-stage base metal veins and replacement bodies (pyrrhotite-sphalerite-galena-chalcopyrite).

The Boya prospect is significantly richer in tungsten than molybdenum; atypical for these deposits. Most of the mineralization is contained within a vein stockwork system in porphyritic intrusive and country rocks, indicating that the deposit is more aptly classified as a porphyry which has associated mineralization in related skarn. The tungsten-rich nature of the Boya prospect may simply reflect post-mineralization deformation. Considering that the molybdenum concentration in these deposits increases closer to the stockwork system and that this occurrence is cut at depth by a gently dipping thrust fault, it is conceivable that the bulk of the molybdenum-rich, porphyry system has been removed by faulting, thus decreasing the overall amount of this commodity.

Although there are no published grade and tonnage values for this occurrence, Moreton (1984), states that the average values of WO_3 and MoS_2 are 0.090 per cent and 0.062 per cent respectively for assays from four diamond-drill holes, over intervals ranging from 15 to 132 metres.

At Boya Hill, quartz-feldspar-biotite porphyry dikes and sills cutting siliciclastics, carbonates and minor volcanics are spatially associated with mineralization and are interpreted as high-level offshoots of a larger intrusive body at depth. Downward coalescing of igneous sills and dikes is supported by diamond drill-hole data.

The mineralized stockwork system is associated with pervasive potassic, phyllic and minor argillic alteration assemblages. Early potassic alteration is associated with quartz veining with high W:Mo ratios whereas later phyllic alteration has high Mo:W ratios. Skarn formed at the same time as early potassic alteration and related tungsten-rich veining. Scheelite occurs as disseminations within skarn and associated calcsilicate hornfels. Late stage base metal veins (pyrrhotite-sphalerite-galena-chalcopyrite) are associated with retrogression of early skarn and are probably the same age as phyllic alteration.

STOCKWORK (PORPHYRY) MINERALIZATION

Vein stockwork mineralization is restricted to the quartz-biotite-feldspar porphyry (QBFP) and to the non-calcareous hornfels. The composition and nature of the stockwork system is variable and reflects that of the surrounding alteration zones. There are two main types of alteration at Boya Hill: an early potassic alteration, which is restricted to the QBFP, and a later phyllic alteration which affects the QBFP and adjacent noncalcareous hornfels.

Potassic Alteration and Associated Vein Mineralization

The early potassic alteration is widespread in the QBFP. It is displayed in two forms: as widespread secondary biotite, and as potassium feldspar flooded zones. Pervasive secondary biotite zones are cut by numerous quartz-potassium feldspar veins from 0.1 to 1.5 centimetres wide. Potassium feldspar also forms vein selvages and grades into the porphyry groundmass. These veins also carry calcite, pyrrhotite, sphene, phlogopite, actinolite, clinopyroxene, epidote, muscovite, apatite, scheelite and minor molybdenite. Pyrrhotite and scheelite contents range from 5 to 15 and 0.2 to 3 per cent of these veins, respectively.

Potassium feldspar flooded zones have the assemblage: potassium feldspar-muscovite-sphene-pyrite-calcite± epidote. No veins are associated with this assemblage and there is negligible mineralization.

"Phyllic" Alteration and Associated Vein Mineralization

Overprinting and grading into zones of potassic alteration is an assemblage labeled "phyllic" by Moreton (1984). It is characterized by muscovite-potassium feldspar-calcite-pyrite-sphene-chlorite-quartz and is related to adjacent quartz-potassium feldspar-calcite-quartz-pyrite-molybdenite-bearing veins. This, as Moreton (*op. cit.*) points out, is not a typical assemblage for the classic definition of this alteration type. The alteration is not pervasive and its intensity is related to vein density. Alteration also affects adjacent noncalcareous biotite hornfels. Associated veins are texturally distinct from those related to potassic alteration.

Most of the molybdenite mineralization occurs in quartz veins associated with this alteration. Two types of veins are described: An early series of randomly oriented veins 0.2 to 25 centimetres wide which contain from trace amounts to over 20 per cent molybdenite. Some of these veins show a ribbon texture suggesting multiple periods of opening. Scheelite is present in only minor amounts. The second set of veins are vertical, east-west trending and crosscut the previously described veins. They are best developed within the QBFP on the Main Face and may contain molybdenite.

Sulphide Veins Associated With "Phyllic" Alteration

A series of base metal veins, which are texturally identical to the molybdenite-bearing veins in the QBFP and biotite hornfels, have alteration halos identical to these within the "phyllic" alteration zones. These veins are peripheral to the molybdenite-bearing vein system and contain quartz and calcite as the main gangue minerals. They are best developed at the Main Face showing where they are generally 0.5 to 10 centimetres wide but can be up to 1.3 metres wide. There are two types of sulphide veins: those carrying mainly arsenopyrite and others with arsenopyrite, pyrite-pyrrhotite, sphalerite and chalcopyrite.

Arsenopyrite-rich veins contain up to 60 per cent sulphides and are commonly associated with breccia. In addition to arsenopyrite, the veins have varying amounts of pyrite, sphalerite, chalcopyrite and galena. Up to 10 000 ppb Au is also reported from one locality. Sphalerite may constitute up to 50 per cent of the arsenopyrite-free veins. No molybdenite was seen in any of the veins but scheelite is present as a minor constituent.

SKARN MINERALIZATION

Skarn developed in several areas of carbonate-rich strata along Boya Hill. It is best developed along West Hill, Night Hawk Hill and Paint Can Hill (Figure 32; Photo 79). Very little limestone is present on the Main Face, so skarn development there is limited. Skarn zones are less than 0.5 metres thick and traceable for only a few metres. West of the Main Face, skarn bodies are typically concordant and up to 1 metre thick and traceable for up to 75 metres. Only minor discordant skarn was described, being up to 0.5 metres thick and very local in nature. Based on mineral assemblages, prograde skarn is calcic. Skarn is never seen in contact with the QBFP. Prograde skarn is believed to have formed at the same time as early potassic alteration in the QBFP. Scheelite was introduced at this time and is present as fine disseminations. Skarn was later retrogressed along the contact with sulphide-rich veins which Moreton (1984) believes were formed at the same time as the "phyllic" alteration.

Main Face Skarns

Calcic skarn along the Main Face zone contains the following assemblages: grossular-quartz-calcite; grossular-clinopyroxene-quartz-calcite; clinopyroxene-quartz and clinopyroxene- plagioclase-quartz. The latter two assemblages contain minor amounts of disseminated scheelite. A pre-retrograde, pyrrhotite-bearing skarn, with up to 80 per cent sulphides, crosscuts the garnet and clinopyroxene skarn bands.

Skarn is locally retrogressed to the assemblage prehnite-pyrrhotite-epidote-clinozoisite-calcite-chlorite-muscovite. The retrograde zones are commonly less than 2 centimetres thick and occur as selvages on the base metal-bearing veins, which are up to 3 centimetres wide and

Photo 79. Skarn mineralization at West Hill, Boya West occurrence. Dark skarn can be seen below the hammer and light coloured limestone or marble above.

composed of quartz and calcite±significant amounts of pyrite, sphalerite, chalcopyrite, arsenopyrite, galena, scheelite and molybdenite.

West and NightHawk Hill Skarns

These areas contain the following calcic skarn assemblages: garnet-vesuvianite; pyroxene-quartz; pyrrhotite-clinozoisite and prehnite-clinozoisite. The pyrrhotite-clinozoisite skarn is dominant and contains 5 to 95 per cent sulphide. Irregular zones of chalcopyrite-sphalerite-bearing pyrrhotite skarn are found associated with an alteration assemblage composed of quartz, zoisite, muscovite, potassium feldspar, chlorite and calcite.

Paint Can Hill

This region is characterized by massive garnet skarn in contact with biotite and calcsilicate hornfels. No mineralization is reported.

VEINS

COPPER VEINS (094L 006)

Several copper-bearing vein occurrences were found within the map area, all in carbonate rocks of unit Ꞓc. One of the more prominent veins has been recorded as a Minfile locality (094L 006, Black Wednesday). It is exposed near the top of a steeply southwest-dipping limestone panel of unit Ꞓc, south of Bluff Creek. This 'vein' is actually a series of anastomosing quartz veins with a composite thickness of 3 to 4 metres; individual veins are up to 1 metre thick. The veins are approximately concordant with bedding and have a strike length of at least 30 metres. Lenses or sheets of limestone between the veins commonly contain zones of trongly silicified rock. These may have been siliciclastic interbeds in the host limestone, or are possibly zones of silicified limestone.

The veins are locally coated with malachite and azurite and orange to red-brown iron oxides. Chalcopyrite and chalcocite are associated with the azurite and malachite staining. A grab sample of the quartz vein with visible mineralization returned 0.86 per cent Cu, 1.2 grams/tonne Ag, slightly anomalous Zn and negligible Au.

Chalcopyrite and tetrahedrite(?)-bearing quartz veins from 0.01 to 1.5 metres thick also occur within unit Ꞓc along the northern extension of the Brownie Mountain anticline. Some of the larger veins are conspicuous and can be traced for some distance. The veins are planar to irregular in shape and generally trend 100° to 110°. The orientation of these veins is roughly parallel to the trend of the axial surface of the Brownie Mountain anticline suggesting they formed in response to folding of the thick, competent carbonate of unit Ꞓc. They contain wallrock fragments, and vugs lined with tiny quartz crystals are common. Malachite and azurite staining is extensive in copper-rich zones. Similar copper-bearing quartz-carbonate veins were found locally in this unit farther northwest, on the ridges between Gataga Mountain and Terminus Mountain.

TETRAHEDRITE-BARITE VEINS

Narrow tetrahedrite and barite-bearing quartz-calcite veins cut Earn Group rocks in the northeastern part of the map area. These veins are only centimetres thick, and discontinuous.

LEAD - ZINC VEINS (094L 025)

A boulder containing sulphides was found approximately 3.5 kilometres northwest of the Broken Bit barite occurrence during the 1995 field season (Figure 26, Ferri *et. al.*, 1996a, b). The area around the boulder was subsequently staked by Cominco Exploration Ltd. as part of its Net property which includes the Broken Bit barite occurrence.

The source outcrop consists of slate and siltstone to siliceous siltstone, interbedded with thin, grey to orange-weathering baritic limestone. Wagner (1997b) suggests that the host lithology is part of the Kechika Group.

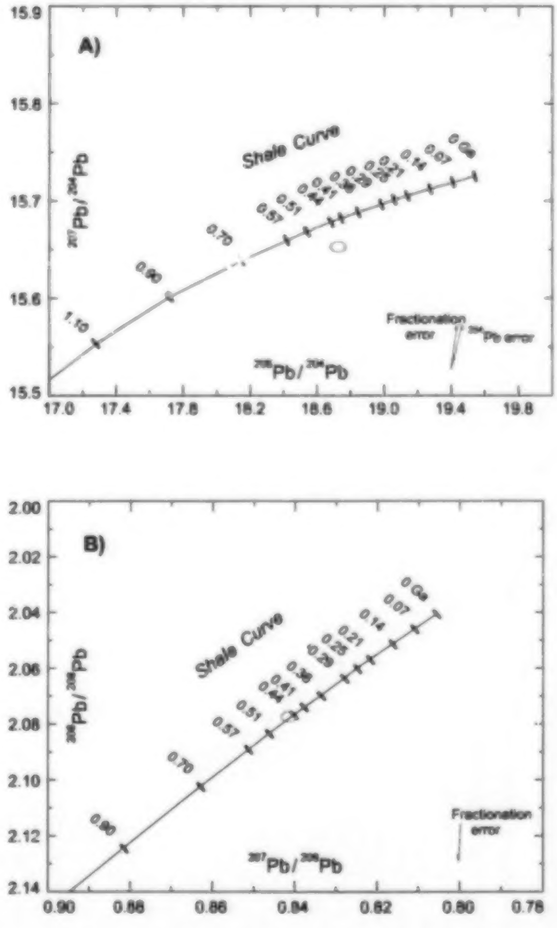


Figure 33. (a) Lead isotopic analyses of samples plotted on $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagram, with shale curve (Godwin and Sinclair, 1982) for reference. (b) Lead isotopic analyses of samples plotted on $^{208}Pb/^{206}Pb$ versus $^{207}Pb/^{206}Pb$ diagram, with shale curve (Godwin and Sinclair, 1982) for reference.

This may be valid, considering the presence of orange-weathering barite layers in similar rocks of Ordovician age some 4 kilometres along strike to the northwest. If they are older, they represent a very small thrust sliver bounded by Cambrian siliciclastics to the west and Earn rocks to the east.

Fractured, silicified siltstone and slate contain galena and sphalerite in quartz-calcite veinlets and as disseminations. Wagner (1997b) reports the mineralization is sporadically distributed over an area some 10 by 8 metres. Cominco Exploration Ltd. reports 6.9 per cent Zn, 206 ppm Pb and 4.5 ppm Ag (Wagner, 1997b). A selected grab sample during our work assayed over 3 per cent Pb, 15.7 grams per tonne Ag, 0.1 per cent Zn and 0.1 per cent Ba (Table 5a).

The nature of this mineralization clearly shows it to be epigenetic. Whether it is related to younger intrusions or represents older sulphides (sedex?) structurally remobilized along a fault or shear zone is uncertain. A sample of galena was analyzed in hopes of obtaining a Pb-Pb isotopic age. This analysis was carried out at the University of British Columbia by J. E. Gabites (*see* Appendix 1; Figure 33). ^{208}Pb, ^{207}Pb, ^{206}Pb, and ^{204}Pb, isotopes were obtained and ratios were plotted against empirically determined Pb isotopic growth curves derived from shale-hosted lead-zinc deposits located within the western ancestral North American miogeocline in Canada (Figure 33; Table 8, Godwin and Sinclair, 1982; Godwin *et al.*, 1988). This point lies on the non-radiogenic side of the ^{207}Pb/^{204}Pb versus ^{208}Pb/^{206}Pb shale-curve but plots at the boundary between clusters defining Silurian and Devono-Mississippian deposits. On the ^{208}Pb/^{206}Pb versus ^{207}Pb/^{206}Pb diagram, the sample plots on the shale curve and indicates a Silurian age.

MULTI-ELEMENT VEINS

There are documented occurrences of vein mineralization, with or without Cu, Zn, Pb, Fe, Ba, F and Ag, in the northern part of the map area in the vicinity of Kitza Creek, the Red River and the Liard River (Roman property). Their origin is speculative. Those along the Liard River may be related to a nearby intrusive, but the source of numerous veins in the Kitza Creek and Red River areas remains problematic.

Red River Area (094M 020)

Vein mineralization along the Red River was first reported in the early 1980s by St. Joseph Exploration as part of a regional exploration program targeting sedex sulphide deposits within the northern Kechika Trough (Miller and Harrison, 1981b, c). Preliminary work along the Red River indicated low grades and this together with the generally poor exposure, discouraged further exploration. The showings are approximately 5 kilometres upstream from the confluence with the Kechika River (Figure 34). There are three main localities of vein mineralization. The western showing is a quartz breccia zone, 3 metres long with sphalerite, galena and pyrite. Smithsonite-bearing quartz-calcite veins were also noted during our mapping in this area (Table 5b). Approximately 500 metres to the east is an outcrop containing quartz veins with minor chalcopyrite and pyrite. Both occurrences are hosted by rocks of uncertain affinity that may be part of either the Road River or the Earn groups.

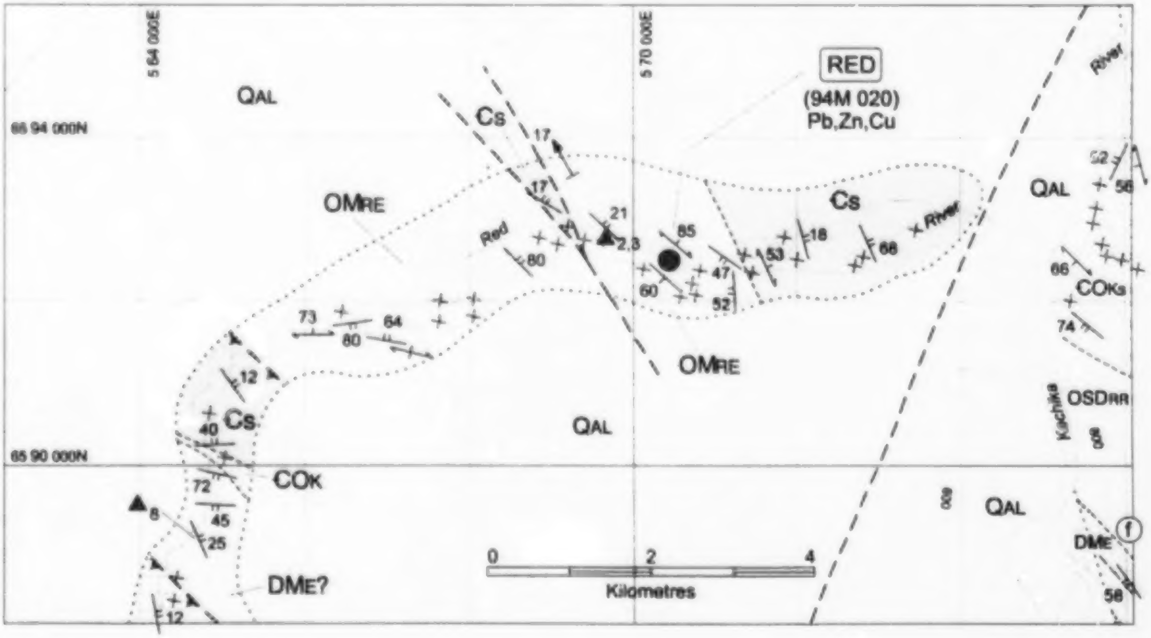
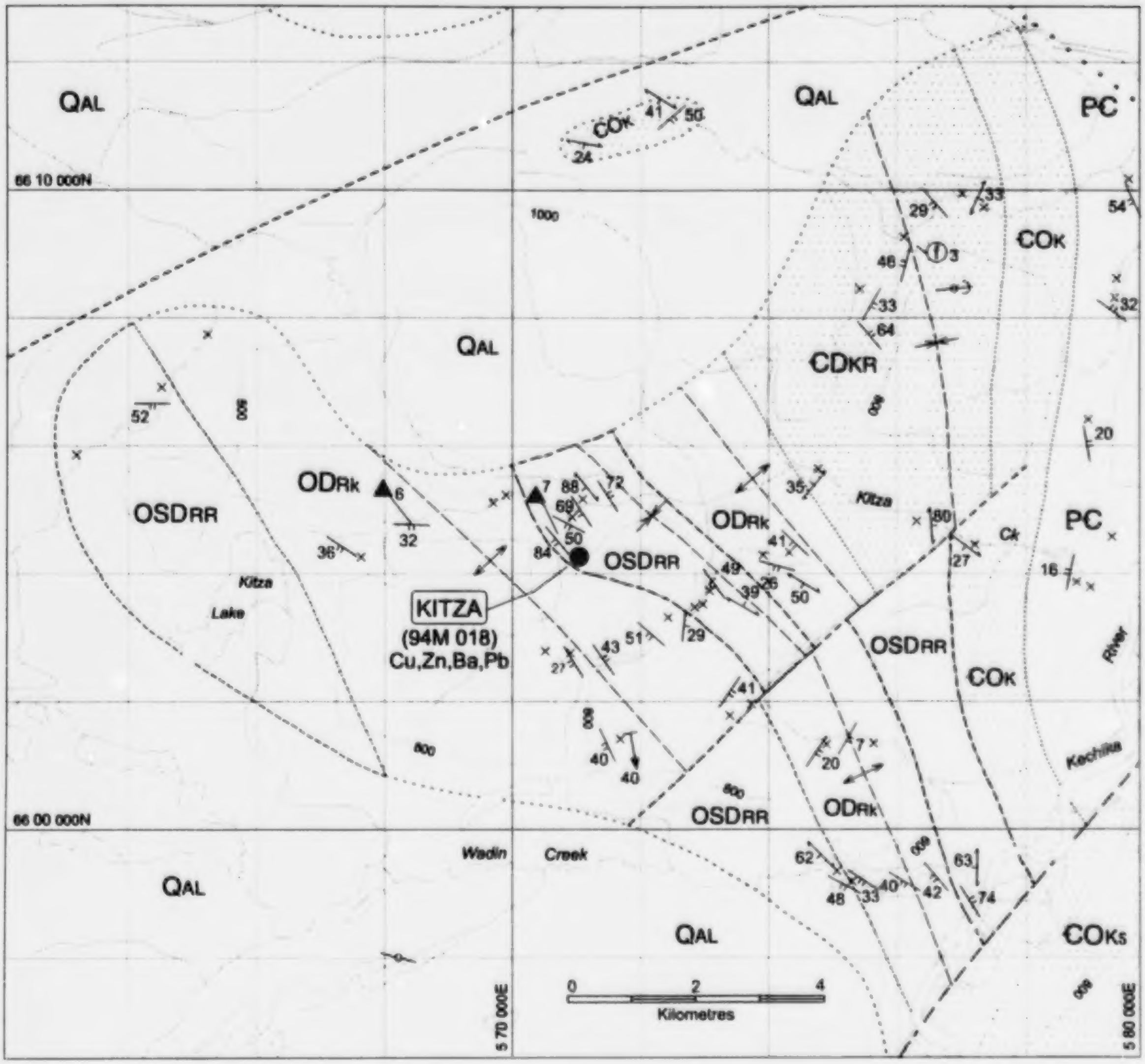


Figure 34. Geology and mineral occurrences along the lower Red River. Symbols, linetypes, *etc.* are identical to those on Figures 2 and 3.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Wadin
Creek
62
63
48
33
40
42
74
QAL
QAL
COKs
0
2
4
Kilometres
5 70 000E
5 80 000E

Figure 35. Geology of the area around Kitza Lake and Kitza Creek. The Minfile occurrence has been placed in the vicinity of a now forfeited claim block which covered an area of anomalous base metal values associated with numerous sulphide-bearing veins.

These rocks also share similarities with lithologies described as the 'Kitza Creek facies' (*see* section on Lithologic Units). Another 500 metres to the east, a vuggy, irregular quartz vein with low grades of galena and sphalerite is exposed in rocks of Cambrian age.

Kitza Creek Area (094M 018)

Mineralization in the Kitza Creek area was discovered by Sulpetro Minerals Ltd. in the early 1980s as part of a regional program along the entire Kechika Trough (Miller and Harrison, 1981a). The veins occur in Kitza Creek facies rocks along a belt 8 kilometres long by 3 kilometres wide, centered roughly 3 kilometres east of Kitza Lake (Figure 35). Several dozen veins are known, each contains one or more of tetrahedrite, honey-brown sphalerite, barite, quartz, calcite and rarely galena. The veins are described as restricted to calcareous mudstones (Miller and Harrison, 1981a). Smithsonite was reported as a matrix in some fault zone breccias and pale green fluorite was found in a few veins (Miller and Harrison, 1981a). The country rocks in the area carry elevated metal levels, and Miller and Harrison speculated that the veining may be related to de-watering of the hostrocks. The low grade of the veins, together with the limited exposure, led to the property being dropped after a few years of preliminary exploration. The possible relationship between these veins and potential sedex mineralization was discussed in the section on 'Sedimentary Exhalative Mineralization'.

Liard River (104P 072)

In addition to mineralization of possible sedex origin, the Roman property covers sulphide-bearing veins. These veins are, in part, interpreted to be much younger and probably related to regional tectonism. However (Rainsford, 1984) suggested some may be part of a feeder system to sedimentary exhalative mineralization. Sulphide veins were observed on the north side of the river, across from the main part of the Roman property. The textures and relationship between various types of vein mineralization is complex and related to at least three phases of deformation. The Earn Group hostrocks contain lenses of pyrite along cleavage planes of the first phase of deformation (D_1). This cleavage is pervasive and related to northeast-verging folding and thrusting in the Northern Rocky Mountains. These lenses are kinked (F_2) by northeast-trending folds, and pyrite is also concentrated in hinge areas of F_2 kinks. These zones show strong carbonate and silicate alteration and associated bleaching. Related to this are thick quartz calcite-ankerite-tetrahedrite veins which cut the foliation. These veins are deformed by late, north-trending kinks (F_3); related fractures in the altered lithologies are coated with sphalerite, galena, marcasite and pyrite. The thick quartz-carbonate veins also cut the salmon and green chert unit (Mount Christie Formation?) that overlies the Earn Group.

A silica-carbonate-altered felsic intrusion immediately east of these showings may be genetically linked to it. The metals may have originated within this felsic body or may have been remobilized from elsewhere in the stratigraphy, possibly from the stratabound mineralization postulated by Rainsford (1984).

SHEAR-CONTROLLED SULPHIDES (094L 022)

Disseminated, patchy galena was found on the southeast side of a ridge some 4 kilometres southeast of Gataga Mountain. It occurs at the base of a sequence of strongly sheared, dark grey to grey-green slates tentatively assigned to unit Ꞓsc, immediately above grey carbonates of unit Ꞓc. This succession is structurally below a slice of the Gataga Volcanics. The galena is confined to a zone of silicification in the lowest 5 to 10 centimetres of the sheared slates; its strike length was not determined. A selected grab sample assayed 5 per cent Pb, 30.1 grams per tonne Ag and 0.6 per cent Zn.

DISSEMINATED MINERALIZATION OF UNKNOWN ORIGIN (094L 028)

A small copper showing crops out approximately 7 kilometres northwest of Gataga Mountain, along the lower slopes of the Northern Rocky Mountain Trench. Interlayered maroon and pale green, micaceous slate to siltstone of unit ꞒPsm is malachite stained. These sediments sit stratigraphically below or interfinger with volcanic rocks of unit ꞒPv. A grab sample of mineralized siltstone contains 0.2 per cent Cu and elevated levels of Ag and Ba.

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APPENDIX 1

U/Pb Analyis of Zircons Recovered from Felsic Tuff Unit (PGf) of Gataga Volcanics

TABLE 7

Fraction[1]	Wt	U	Pb*[2]	^{206}Pb[3]	Pb[4]	^{208}Pb[5]	Isotopic ratios (±1)[6]			Apparent ages (±2
	mg	ppm	ppm	^{204}Pb	pg	%	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb	^{206}Pb/^{238}U
FFE-95-1-5: Felsic volcaniclastic, unit PGf										
A	0.036	91	11	1387	16	14.8	0.11044(0.10)	0.9507(0.26)	0.06243(0.18)	675.3
B	0.036	89	11	514	44	15.6	0.10861(0.13)	0.9345(0.41)	0.06240(0.32)	664.7
C	0.032	87	10	786	25	14.6	0.11007(0.12)	0.9463(0.33)	0.06236(0.25)	673.1
D	0.025	126	15	163	151	16.4	0.11109(0.28)	0.9563(1.1)	0.06243(0.93)	679.1
E	0.046	130	14	881	44	15.4	0.10200(0.11)	0.8747(0.30)	0.06219(0.21)	626.1

[1] All zircon fractions except those listed as T1, T2, etc. which are titanite. Most zircon fractions are air abraded (exceptions noted in text).

[2] Radiogenic Pb

[3] Measured ratio corrected for spike and Pb fractionation of 0.0043/amu± 20% (Daly collector) and 0.0012/amu ± 7%(Faraday collector).

[4] Total common Pb in analysis based on blank isotopic composition

[5] Radiogenic Pb

[6] Corrected for blank Pb, U and common Pb. Common Pb corrections based on Stacey and Kramers (1975) model at the age of the rock or the 207Pb/206Pb age of the fraction. Error for 206Pb/238U ages not listed. See concordia plots in Figure 12 for magnitude of these errors.

Data is plotted in Figure 12.

Pb Isotopic Analysis of Galena from a Showing in the Gataga Area; Sample FFe95-27-7

This is modified from a report prepared by Janet E. Gabites; Geochronology Laboratory, Department of Geological Sciences, U.B.C.

The results of lead isotopic analysis of galena from a showing in slate from the Gataga area are reported below, and plotted on Figures 33a and b. The galena was collected from within a vein or stockwork system crosscutting the immediate hostrocks. Original mapping suggested that the hostrocks are part of the Devonian Earn Group. The alternative interpretation is that they belong to the Kechika Group, which is Cambro-Ordovician.

The analysis of sample FFe95-27-7 has been plotted against the shale curve of Godwin and Sinclair (1982). This model curve is a reference for the growth of lead in upper continental and upper crustal environments in the Canadian Cordillera, defined using data from stratiform deposits in British Columbia and Yukon Territory (Godwin et al., 1988).

The ^{206}Pb/^{204}Pb v. ^{207}Pb/^{204}Pb isotopic ratios plot below the shale curve, near the Silurian-Devonian boundary. In comparison with the data that were used to define the shale curve (Godwin and Sinclair, 1982), this sample plots between the clusters of galena of Devonian and Silurian ages from the Selwyn Basin area. The relationship is clearer in Figure 33b, the ^{207}Pb/^{206}Pb v. ^{208}Pb/^{206}Pb plot. The small peak of

^{204}Pb is not used in the isotopic ratios in this plot, thus removing a major source of analytical error. Sample FFe95-27-7 plots on the curve, in the Late Silurian.

Thus the isotopic signature of galena in this showing is consistent with mineralization being of Silurian age. The lead has a continental source consistent with other shale-hosted deposits in the Canadian Cordillera.

Analytical Techniques

Small clean cubes of galena were hand picked, washed, and dissolved in dilute hydrochloric acid. Approximately 10-25 ng of the lead in chloride form was loaded on a rhenium filament and isotopic compositions were determined using a modified VG54R thermal ionization mass spectrometer. The measured ratios were corrected for instrumental mass fractionation of 0.12% per mass unit, based on repeated measurements of the N.B.S. SRM 981 Standard Isotopic Reference Material. Errors reported in Table 8 were obtained by propagating all mass fractionation and analytical errors through the calculation.

Table 8

Sample Number	^{206}Pb/^{204}Pb	^{206}Pb/^{204}Pb % error	^{207}Pb/^{204}Pb	^{207}Pb/^{204}Pb % error	^{208}Pb/^{204}Pb	^{208}Pb/^{204}Pb % error	^{207}Pb/^{206}Pb	^{207}Pb/^{206}Pb % error	^{208} b	
FFe95-27-7	18.658	0.033	15.651	0.022	38.741	0.064	0.838837	0.024	2.076376	

Data plotted on Figure 33.